IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, *et al.*,	)	
	)	
***Plaintiffs*,**	)	
	)	
v.	)	**Case No. 4:05-cv-00329-GKF-PJC**
	)	
TYSON FOODS, INC., *et al.*,	)	
	)	
***Defendants*.**	)	
	)	

DECLARATION OF DR. TIMOTHY J. SULLIVAN, Ph.D.

1. My name is Timothy J. Sullivan. I hold a Ph.D. in biological sciences and am President of E&S Environmental Chemistry, Inc., and E&S Environmental Restoration, Inc.

2. I have been retained by the Defendants in this matter to review and assess various aspects of Plaintiffs' claims including those regarding the alleged sources of contamination in the Illinois River Watershed.

3. I previously authored and submitted to my clients an expert report detailing my work and conclusions in this matter. I understand that this report was served on Plaintiffs. I incorporate that report herein by reference.

4. If called to testify at trial, I would testify consistent with the opinions expressed in that report.

I declare under penalty of perjury that the foregoing is true and correct.

Executed 7 June, 2009.

[signature]

Timothy Sullivan
E&S Environmental Chemistry, Inc.

UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, ex. rel. W.A. DREW EDMONDSON, in his capacity as ATTORNEY GENERAL OF THE STATE OF OKLAHOMA and OKLAHOMA SECRETARY OF THE ENVIRONMENT, J. D. Strong, in his the capacity as the TRUSTEE FOR NATURAL RESOURCES FOR THE STATE OF OKLAHOMA,	
Plaintiffs,	
	Case No. 05-CV-329-GKF-SAJ
v.	
TYSON FOODS, INC., TYSON POULTRY, INC., TYSON CHICKEN, INC., COBB-VANTRESS, INC., AVIAGEN, INC., CAL-MAINE FOODS, INC., CAL-MAINE FARMS, INC., CARGILL, INC., CARGILL TURKEY PRODUCTION, LLC, GEORGE'S, INC., GEORGE'S FARMS, INC., PETERSON FARMS, INC., SIMMONS FOODS, INC., and WILLOW BROOK FOODS, INC.,	
Defendants.	

EXPERT REPORT OF

Timothy J. Sullivan, Ph.D.
President

E&S
Environmental
Chemistry, Inc.

January 29, 2009

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bacteria (which can substantially skew an average concentration) has little or no meaning. This is largely why bacterial standards are based on calculation of a geomean (which is not heavily skewed by a single high value) of five or more samples.

2. *Concentrations of P and fecal indicator bacteria in the IRW are similar to streams and reservoirs commonly found elsewhere in Oklahoma, the region, and the nation.*

Plaintiffs' consultants allege that concentrations of P and fecal indicator bacteria are high in the waters of the IRW. Nevertheless, they do not adequately compare such measurements with data collected elsewhere. Of interest in this regard are concentrations throughout the state of Oklahoma, the ecoregions in which the IRW is located, the general region of the country in which the IRW is located, and the United States as a whole. I did compile available data, examine publications, and conduct analyses to illustrate such comparisons. Results are described below.

<u>Spatial Patterns in Oklahoma</u>

Failure to support water quality beneficial uses is quite common in Oklahoma. For example, the Oklahoma Water Resources Board has established an ambient monitoring network of 100 active permanent water quality monitoring stations which are evaluated annually. According to the Beneficial Use Monitoring Program (BUMP) Draft 2007 Streams Report (OWRB 2007), only 11 of those monitoring sites fully supported the primary body contact recreation beneficial use during that year. The Oklahoma Water Quality Assessment Integrated Report for 2004 (ODEQ 2004) designated 33,221 miles of rivers and streams in the state as having the beneficial use of primary body contact recreation. Of those river and stream miles, only 471 miles were determined to be fully supporting the beneficial use, and 6,546 miles were determined to be not supporting the beneficial use. The remaining miles were not assessed or were judged to have insufficient information. Thus, of the river and stream miles determined by the state of Oklahoma to be either supporting or not supporting the primary body contact recreation standard, 93% were judged to not support this beneficial use.

Figures 2-1 through 2-3 show the concentrations of total P in stream water at sampling sites throughout Oklahoma. Data are presented as the geomean of available data for all sites represented by five or more samples during the period 2000 to 2007. Three separate maps are shown, representing three different sources of data: U.S. Geological Survey, EPA STORET, and Oklahoma Water Resources Board. These maps show that stream water total P concentration is highly variable throughout the state of Oklahoma, regardless of which major data source we examine. Concentrations of total P in stream water inside the IRW are not appreciably different from streams outside the IRW. The occurrences of concentrations above the 0.037 mg/L Oklahoma water quality standard for Scenic Rivers are no more prevalent inside the IRW as compared with outside the IRW. Note that sites that have geomean total P concentration higher than the standard are shown on the maps as orange bars; green bars indicate that the geomean concentration at a given site is not above the standard.

Impacts to surface waters by fecal bacteria derived from mammals and birds is a widespread phenomenon throughout the United States, and such contamination is commonly identified using indicators of fecal inputs, especially FCB and *E. coli*. For example, there were 8,695 miles of stream listed by the state of Oklahoma as water quality impaired (303(d) list), and 70% of those throughout Oklahoma, in areas where poultry operations are numerous and in areas where poultry operations are scarce (Figure 2-5).

Furthermore, there are many locations throughout Oklahoma where fecal indicator bacteria concentrations are substantially higher than they are in the IRW. The fact that portions of the Illinois River and its tributaries are listed as water quality impaired as a consequence of fecal indicator bacteria concentrations is not a cause for alarm. The issue is well known and is nationwide in scope.

Data presented for individual data sources (e.g., USGS, OWRB, STORET) in many of the preceding figures are combined into four maps, one for TP and one for each of the fecal indicator bacteria variables. These data are shown in Figures 2-14 through 2-17**.** The spatial patterns in the data are very clear, indicating that neither the concentration of P nor the concentration of any of the three fecal bacteria indicators is high in the IRW, compared with elsewhere in Oklahoma. Furthermore, the few instances of relatively high concentrations within the IRW occur adjacent to, or shortly downstream from, municipal waste water treatment facilities.

Concentrations of enterococcus above the Primary Body Contact Recreation standards are ubiquitous within the IRW. Similarly, enterococcus concentrations are above the Primary Body Contact Recreation standard at 90% (OWRB data) to 96% (STORET data) of the locations within Oklahoma where sufficient data are available to calculate a geomean of five samples (Figures 2-6 and 2-7). This suggests that either poultry litter is not the principal source of enterococcus to stream water or that poultry litter application is a common occurrence statewide. The spatial distribution of poultry operations within Oklahoma from agricultural census data (Figure 2-5) shows that poultry farming is confined primarily to eastern Oklahoma. Thus, consideration of the spatial patterns in enterococcus concentrations and poultry farming suggests that sources of enterococcus other than poultry are commonly responsible for the frequent occurrence of concentrations above the standards.

As illustrated in the series of maps described above, any allegation that TP or fecal bacteria indicator concentrations in the IRW are unusually high compared to other water bodies in Oklahoma, thereby representing an immediate and unusual health threat, is not borne out by the available data.

Stevenson (2008, page 17) reported that the median concentrations of total P in IRW streams were 0.076 mg/L in summer 2006, 0.057 mg/L in spring 2007, and 0.067 mg/L in summer 2007. The median for streams sampled by Plaintiffs' consultants for this case and reported in Dr. Olsen's database, under all flow conditions, was similar, 0.062 mg/L. Dr Stevenson (2008, page 17) concluded that these concentrations were:

> ***…relatively high in the IRW compared to many other regions***

But he did not discuss results from other regions and provided no basis or context for this statement. I have examined total P data from several large surveys and assessments, and found that concentrations of total P in the IRW are not unusual compared with data from many other locations. These results are summarized below.

under all flow conditions, were above some water quality standards, but nevertheless were about half as high as the median values reported by USGS for the 250 nationally representative riverine monitoring stations.

Based on results of analyses summarized above, compared with streams and reservoirs sampled in many studies throughout Oklahoma, the region of the IRW, and the United States as a whole, in a number of large surveys, neither the concentrations of TP nor fecal coliform bacteria in the IRW are unusual.

3. Water quality data in the IRW reflect a variety of sources associated with a mix of land uses.

The land area of the Illinois River watershed is a complex patchwork of urban, rural residential, agricultural, and forest land uses (Figure 3-1), with a variety of potential P and fecal indicator bacteria sources to stream water. Land application of poultry litter is only one among many potential sources. The most important sources of P to stream water are probably waste water treatment plant effluent, livestock, septic systems, erosion, and runoff from urban and other developed areas. The most important sources of fecal indicator bacteria are probably livestock, septic systems, urban runoff, accidental sewage discharge and other sewage bypasses, river recreationists, and wildlife. All of these sources contribute P and/or fecal indicator bacteria to stream water, dependent upon location, rainfall, flow conditions, human and animal populations, and variations in land use. Most of these sources were ignored or unreasonably dismissed as unimportant by the Plaintiffs' consultants in this case.

Because the land uses within the watershed are so patchy (see Figure 3-1) and because so much of the urban land use (a major source area of both P and fecal indicator bacteria to streams) is located in the headwater regions of the watershed, it may be impossible to discriminate precisely among the various nonpoint P and bacteria sources based on observed geographic patterns in P or bacterial concentration. Certainly the Plaintiffs' consultants did not design and implement a sampling program that discriminated among the various potentially important sources of NPS pollutants.

Headwaters are important in this assessment because stream flows in headwater areas are lower than further down the stream system, and therefore inputs of P and bacteria have larger influence on concentrations in stream water in the smaller headwater streams. Furthermore, contamination of streams with waste water treatment plant effluent and urban runoff in the headwater areas makes it difficult to evaluate the importance of multiple potential nonpoint sources of P and/or fecal indicator bacteria in agricultural and rural residential lands further downstream. Thus, streams in this watershed have concentrations of P and fecal indicator bacteria above water quality standards in the upper reaches of many of these stream systems, well above the mainstem Illinois River. The relative importance of each source is not known. These potential sources of P and bacteria cannot be ignored in any serious attempt to evaluate the possible causes of concentrations above standards at some locations in the IRW. There is no justification for singling out the poultry industry as the cause of P or fecal indicator bacteria above water quality standards in this watershed, especially given the large populations of people (on both sewered and septic waste water treatment) and cattle in the IRW. In addition, because of differences in the timing of improved land and facilities management, WWTP construction projects, and continued growth in the IRW, spatial patterns may be further obscured.

It is well known that the land uses that are common in the IRW are often associated with contributions of nutrients such as P and fecal indicator bacteria to streams. It is also well known that it is very difficult to quantify the relative contributions from the various source types. EPA (2002, page 14) stated the following:

> ***Detecting and ranking sources of pollutants*** *(to streams)* ***can require monitoring pollutant movement from numerous potential sources, such as failing septic systems, agricultural fields, urban runoff, municipal sewage treatment plants, and local waterfowl populations. Often, states are not able to determine the particular source responsible for impairment.***

In the IRW, Plaintiffs have not conducted the monitoring identified by EPA (2002) as required to determine the particular source(s) responsible for impairment of the streams in the watershed with respect to existing water quality standards for total P and fecal indicator bacteria. However, Plaintiffs' water quality data do allow a general assessment of source areas of P and fecal indicator bacteria; concentrations of these constituents tend to be highest downstream from urban areas and WWTP facilities (see discussion in Section III.5).

Land use in the IRW includes a large amount of agricultural land, most of which is used for pasture and hay production. Urban lands also occur, and are mainly found in the upper reaches of the watershed, in the headwater areas of the Illinois River and several of its tributary streams. It is well known that watersheds having agricultural and urban land use are more likely to receive inputs of nutrients to streams and to have their drainage waters classified as eutrophic than are watersheds having forested land use (Alexander and Smith 2006).

4. *There are large numbers of people and their animals in the IRW, and Plaintiffs' consultants did not fully consider their importance as potential sources of nutrients and fecal indicator bacteria to stream waters within the watershed. Plaintiffs' consultants also did not fully consider the importance of the rapid increase in the human population that has occurred within the IRW in recent decades.*

<u>Current and Recent Population Estimates</u>

Plaintiffs' consultants largely ignored the substantial current human and cattle populations in the IRW and the extent to which the human population has been increasing in recent years, with concomitant increased potential for NPS contributions to streams.

Based on the U.S. Census, there were about 237,000 people in the IRW in the year 2000, of which approximately 160,500 lived in sewered communities, and 76,500 lived in rural areas, presumably on septic systems (Table 4-1). Such a large number of people would be expected to contribute NPS pollutants to stream waters within the watershed regardless of whether or not poultry litter had been land-applied. Pollutant sources would be expected to include bacteria and nutrients contributed via human waste (for example, from waste water treatment plant effluent, septic system drainage, leaking sewer pipes, accidental bypasses of raw sewage, land application of biosolids) and via pet waste. In addition, P can be contributed from soaps and other household products, lawn and garden fertilizer, and urban runoff from impervious surfaces (roofs, roads, sidewalks, parking lots, etc); such runoff would include nutrients and bacteria from fertilizers and animals such as birds, deer, and other wildlife, as well as pets. Roads (especially dirt roads), culverts, and stream banks from which soil-holding trees and other plants have been removed are well-known sources of erosion. Erosion includes the movement (via water, gravity, and/or wind) of soil from the land surface to a stream. It preferentially involves movement of the smaller soil particles (especially clay size particles), and erosion can carry a substantial amount of P adsorbed to soil particles.

I estimate, using American Veterinary Medicine Association estimates for 2001 of 1.7 dogs and 2.2 cats per household in the United States (http://www.avma.org/reference/marketstats/ownership.asp) together with the U.S. Census estimate of 2.67 people per household (http://www.petpopulation.org/faq.html) and the human population estimates given in Table 4-2, that there are over 189,000 dogs and 244,000 cats in the IRW. This assumes that these national estimates are applicable to the IRW, so there is some uncertainty in these estimates. Regardless, it is clear that there are large numbers of dogs and cats in the watershed. It is also obvious that these pets are especially numerous in the upper reaches of the watershed where most of the people live. Pet waste constitutes an important potential source of fecal indicator bacteria and P to urban runoff.

It is noteworthy that developed areas, which include most of the people and therefore many of the pets that reside within the watershed, also contain relatively high percentages of impervious land, from which contaminants from pets, fertilizer application, erosion, and other sources can move rapidly and efficiently to streams. This pollutant transport pathway is accentuated by storm drains, gutters, and roadside ditches that are constructed in urban areas in order to facilitate efficient movement of water into streams during rainstorms. Such water routing infrastructure is an important tool for reducing flooding in urban areas. However, it also provides an efficient conduit for transporting contaminants from the urban landscape to streams. Waste from urban wildlife, including deer, rodents, and birds, as well as cats and dogs, can further add to the flux of contaminants to streams in the urban areas.

Defendants' expert, Dr. Clay (2008), estimated that there are approximately 199,000 cattle, 166,000 swine, 8,000 horses, and 2,000 sheep present in the watershed. Cattle, in particular, have access to streams and streamside (riparian) areas throughout the watershed. Cattle tend to spend a disproportionate amount of their time in and adjacent to streams because such areas provide a source of water, often a source of shade, and an opportunity for cooling during summer months (Clay 2008).

Plaintiffs' consultants contend that cattle do not contribute P to the IRW because they merely recycle the P that is already present in the forage that they consume. This contention reflects a complete misunderstanding of NPS pollutant transport processes. As discussed in Section III.17 of this report, the mere presence of P within the watershed reveals nothing about the propensity of that P to move into a stream; one must also consider the transport opportunities and pathways. Similarly, one cannot ignore the importance of cattle-mediated transport of P from the location of forage ingestion in a pasture directly to the stream or to the riparian area adjacent to the stream. This is critically important because P is typically not readily transported from pasture to stream. Rainfall on much of the surface of a pasture tends to infiltrate into the soil where the P can become adsorbed, rather than running off the surface as overland flow (see discussion in Section III.7 of this report). In contrast, cattle that have free access to streams can directly deposit their feces (with its P and bacteria content) into a stream or to the adjacent riparian land that may be hydrologically active, from which transport to the stream can readily occur during a rainstorm. Thus, the actions of cattle, consuming forage throughout the pasture and then preferentially depositing their feces in or near the stream, constitute an important source contributing P and fecal indicator bacteria to streams in the IRW that was largely ignored by Plaintiffs' consultants.

It is largely because cattle can represent a major NPS pollutant transport mechanism in pasture settings that agricultural best management practices (BMPs) commonly entail construction of fences (with associated off-stream watering systems) to keep cattle out of riparian zones and streams. Intended benefits of riparian fencing include reduced contamination of stream water with livestock feces and its associated nutrient and bacteria content, reduced trampling of riparian vegetation, and reduced stream bank and riparian erosion. Riparian fencing resource protection actions occur nationwide, in many cases funded by the federal government.

It is well-recognized that cattle pose an important source of NPS pollution to streams. In fact, Total Maximum Daily Load (TMDL) analyses in watersheds throughout much of Oklahoma typically conclude that cattle constitute the principal source of fecal indicator bacteria to streams (See discussion of this issue in Section III.6 of this report). Nevertheless, Plaintiffs' consultants largely ignored or dismissed the importance of cattle in the IRW, despite the large numbers of cattle present and the wide prevalence of their access to streams within the watershed.

Plaintiffs' consultants also failed to fully address the fact that feces from an estimated 170,000 swine that live in the IRW are commonly land applied. Waste water treatment biosolids have also been land applied (Jarman 2008). Plaintiffs' consultants did not appropriately address these potential sources of contaminants to stream water, but instead focus on poultry litter, nearly to the exclusion of other known and suspected sources of P and fecal indicator bacteria.

Change in Populations Over Time

The human population in the IRW has been increasing dramatically for the past several decades. Between 1990 and 2007, it increased by about 77% (Table 4-2). In fact, northwest Arkansas has been one of the fastest growing metropolitan areas in the United States in recent years. The total human population in the watershed has increased from about 168,000 people in 1990 to about 297,000 people in 2007 (Table 4-2).The estimated total human population in the IRW increased by over 40% just within the decade of the 1990s. Much of this increase has occurred in the headwater areas of the IRW in the northeastern portions of the watershed. Changes over just a seven year period of time are mapped in Figure 4-1. Human population increases have been especially pronounced in the upper (easternmost) part of the watershed.

Along with the large increase in human population has been a large amount of construction: of housing, shopping centers, and other human infrastructure. Construction activities and urban development are especially widespread throughout the headwater portion of the watershed. For example, Grip (2008) mapped, from examination of aerial photographs and existing maps, new land development in a study area between Rogers and Fayetteville, within the IRW. The study area comprised 152 square miles. Mr. Grip obtained aerial photographs that covered the study area, corresponding to four time periods: 1976-1982, 1994-1995, 2001, and 2006. Developed areas that involved residential and commercial development were identified and mapped, excluding any development that was focused on golf courses, parkland, forestry, crops or pasture. During the initial time period examined (1976-1982), 12.6% of the study area was classified as developed. By 1994-1995, this increased to 22.4%; by 2001, it increased to 29.4%. The cumulative development by 2006 had increased to 39.3%, more than three times the amount of developed land in the earliest period examined (approximately 24 to 30 years previously).

With construction and urban development, there is a substantial increase in the amount of impervious land surface (pavement, roofs, parking lots, compacted soils, etc). Runoff during rainstorms from these impervious areas is largely not directed down through soils (which could remove bacteria from the drainage water), but rather flows overland and through storm drains, providing direct conduits for bacterial and nutrient transport from the ground surface to stream water. Thus, eroded sediment and also bacteria and P deposited on the ground surface by pets, hobby farm livestock, or wild mammals and birds can be efficiently transported from such areas to streams. For this reason, urban areas and developed areas commonly constitute important sources of NPS pollutants to streams. Plaintiffs' consultants have ignored the rapid increase in the human population within the watershed, along with the concomitant large increase in such potential sources of stream pollution.

5. *Effluent and drainage water from urban areas in general, and municipal waste water treatment plants in particular, are major sources of P to surface waters in the IRW.*

Urbanization is well-known as a major source of NPS pollution in the United States (Dillon and Kirchner 1975, Novotny 1995). Nevertheless, it was not fully considered by Plaintiffs' consultants in this case. Other than providing a limited and incomplete evaluation of waste water treatment effluent sources to streams and deleting watersheds having urban land use from some analyses, aspects of urban contribution of NPS pollution were generally not investigated by Plaintiffs' consultants.

My analyses show that spatial patterns in measured total P concentrations in stream waters of the IRW indicate an association with urban land use, and especially with the location of WWTP effluent discharge. Analyses conducted and reported by Defendants' expert Dr. Connolly (2008) further support this conclusion. As described below, highest values of stream total P concentration tend to be located downstream of urban land use and especially downstream of WWTP effluent sources to the streams. Plaintiffs' own data show that the sites that exhibit the highest concentration of total P, expressed as the geomean of five or more samples at a given location, are immediately downstream of the locations of WWTPs, sewage lagoons and/or urban areas.

Plaintiffs' consultants ignored or failed to recognize that stream water P concentrations in the IRW tend to be highest immediately downstream of urban pollution sources. Their analyses were directed towards portions of the watershed assumed to receive land application of poultry litter, and they failed to fully consider the presence of other potential sources of the same constituents that they claimed were contributed to streams from poultry litter application.

As an example, Plaintiffs' consultants collected paired stream samples above and below three waste water treatment plant effluent discharge locations. The resulting total P data are depicted in Figure 5-1, showing that the concentrations of total P in the streams were generally below the 0.037 mg/L standard at the locations above the WWTPs, but substantially higher immediately downstream from the WWTPs. Plaintiffs' consultants did not report such observations in their various reports for this case.

Similarly, an analysis of data collected by Plaintiffs' consultants at variable distances downstream from several WWTP locations (shown in Figure 5-2) illustrate that concentrations of total P in stream water tend to be highest immediately downstream of the location of the WWTP effluent discharge point, and subsequently decrease further downstream **(**Figure 5-3). Similar results were found by Haggard et al. (2001) in an investigation of the effects of the Columbia Hollow WWTP on Spavinaw Creek, Arkansas; they found a marked increase (about 8 to 25 times higher) in soluble reactive P in the stream immediately below the point of WWTP discharge compared with above the discharge, with a gradual decline in the P concentration in the downstream direction below the WWTP. The concentration of P in stream water decreases gradually in a downstream direction from the WWTPs in part because P settles to the stream sediment. The P that accumulates in the sediment can later be remobilized by high stream flows or in response to changing equilibrium conditions between the stream water and the sediment. Haggard et al. (2001) further concluded that the nutrient retention capacity of the stream was greatly reduced as a consequence of the point source. They concluded that:

> ***PS [***point source***] inputs diminish the ability of the stream to withstand other anthropogenic nutrient inputs***

All of these spatial patterns observed in the Plaintiffs' database illustrate the strong association between WWTP effluent (and also urban land use in general) and the occurrence of relatively high concentrations of total P in streams in the IRW. These patterns suggest that the largest sources of P to streams in the IRW are likely associated with urban development. This finding is not new or surprising. As discussed more fully below, urban development is commonly associated with both point and nonpoint source pollution of streams. There is a great deal of urban development in the IRW, and much of that development is recent. Nevertheless, Plaintiffs' consultants generally chose to focus on a presumed linkage with land application of poultry litter, almost to the exclusion of other sources, including the urban sources that their own data implicate as critically important in this watershed.

The finding that stream P concentrations in the IRW are strongly associated with waste water treatment effluent discharge is not new. The Arkansas Department of Pollution Control and Ecology, Water Division (ADPCE 1995) reported results of a study on water quality and biological response in Sager Creek in response to the effects of waste water discharge into the creek from the City of Siloam Springs. Stream samples were collected between July 1993 and June 1994 above and below the point of Siloam Springs waste water treatment plant effluent discharge into Sager Creek. The work was done in response to objections by the State of Oklahoma to proposed discharge permit modifications. Water quality samples were collected and analyzed for total P (and other parameters) approximately once every two months during the one-year study. Two sample sites bracketed the waste water treatment plant: site SAG07 was located 500 ft above the outfall, and site SAG09 was located 500 ft below the outfall. The median (of six samples) total P concentration was 0.06 mg/L at site SAG07, which increased dramatically to 1.38 mg/L at site SAG09, presumably due to the influence of the effluent contribution to the stream. In addition, samples were collected during a low-flow period on June 28, 1994 and during a high-flow event on November 16, 1993. During both flow regimes, stream concentrations of total P were relatively low upstream from the treatment plant, but dramatically higher (especially during low flow conditions) at the site (SAG09) immediately downstream from the waste water discharge (Figure 5-4). During high flow conditions, the concentration of total P increased by more than a factor of 1.5 from immediately above to immediately below the WWTP; during low flow, the difference was more than a factor of 20.

Haggard et al. (2004) reported soluble reactive P (SRP) concentrations immediately downstream of WWTPs on Spring Creek and Sager Creek in the IRW in July 2002. Concentrations of SRP in stream water below the respective WWTP exceeded 1.5 mg/L in Sager Creek and 6 mg/L in Spring Creek; these concentrations were more than an order of magnitude higher than at the sampling locations above the WWTPs and more than an order of magnitude higher than the water quality standard for Scenic Rivers in Oklahoma. Haggard et al. (2004) concluded, based on their study and also numerous other literature citations that:

> ***Phosphorus concentrations in streams generally show a sequential decrease with increasing distance from municipal WWTP effluent discharge.***

Thus, the importance of WWTPs to stream P concentrations in the IRW and elsewhere is not new information. This has been well known for a long time (See studies cited by Ekka et al. (2006) and study by Haggard et al.(2003). Ekka et al. (2006) published an in-depth study of waste water P contributions to streams and stream chemistry in 2002 and 2003 from the cities of Fayetteville, Rogers, Springdale, and Siloam Springs in NW Arkansas. Effluent discharge significantly altered water chemistry, including P concentration, in Mud Creek, Osage Creek, Sager and Flint Creeks, and Spring Creek. These are all tributaries to the Illinois River within the IRW. Mean discharge (stream flow) downstream from the effluent inputs increased from 2 to 57 times compared with the discharge measured upstream of the WWTPs. This illustrates that these headwater streams are effluent dominated. The Fayetteville and Rogers WWTPs discharged water with average total P concentrations of 0.25 and 0.35 mg/L during the study period into Mud and Osage Creeks, respectively. The Springdale WWTP discharged an average effluent TP concentration of 4.4 mg/L into Spring Creek. Average effluent P concentration was not available from the Siloam Springs facility, but it appeared that the change in dissolved P concentration in Sager and Flint Creeks was somewhere between those of Spring Creek and Mud or Osage Creeks (Ekka, 2006). Results from this study showed that stream SRP concentrations increased several fold downstream from effluent inputs (Table 5-1). The most profound effect of WWTP effluent on stream P values was in Spring Creek, which had the highest SRP concentration measured in the study (7.0 mg/L in August 2002). This is more than 189 times higher than the 0.037 water quality standard that is applicable to the main stem rivers in this watershed. Ekka et al. (2006) concluded from his study of streams in the IRW that:

> ***point sources such as municipal waste water treatment plant (WWTP) effluent discharges still exert a prominent influence on dissolved phosphorus (P) concentrations and transport in Ozark streams, particularly in northwest Arkansas, USA (***several cited references***)***

Effluent discharges increase the concentration of P in the water column, and also increase P in the stream sediment (Ekka et al. 2006 and numerous other citations provided by Ekka et al. 2006). As a consequence, Ekka et al. (2006) concluded that:

> ***The influence of WWTP effluent discharge on benthic sediments is generally much greater than other external factors, such as agricultural land use and nonpoint source pollution in the Ozarks (Popova et al. 2006).***

The ability of stream sediments to adsorb P is often much less downstream from effluent discharge points, compared with locations upstream (Ekka, 2006). This can cause P concentrations in stream water to be higher, in response to inputs from any source, as a consequence of the P contributed to the stream sediments from the effluent discharge.

Haggard et al. (2003c) sampled 30 stream sites in the IRW from 1997 to 2001, including sampling sites on the main stem Illinois River, Clear/Mud Creeks, Osage Creek, and Spring Creek. They concluded that:

> ***The spatial distribution of these sites clearly identified elevated P concentrations at the Illinois River at Highway 59*** *[near the Arkansas/ Oklahoma border]* ***were likely from a single WWTP*** *[Springdale]* ***over 46 kilometers upstream… Over 35% of the P transported during surface runoff conditions was likely from resuspension of P retained by stream sediments. Thus, these sediments may represent a considerable transient storage pool of P after management strategies are utilized to reduce elevated P concentrations at the Illinois River.***

Dr. Olsen claimed, based on his principal components analysis (PCA), that samples for which his first principal component (PC1) was equal to or above his designated cutoff value of 1.3 exhibited what he identified as a unique poultry waste signature. Yet his own data show that base flow stream sites having PC1 above 1.3 are largely located immediately downstream of urban areas and WWTPs (Glenn Johnson 2008, his Figure 3-16). Based on this observed spatial pattern, Dr. Glenn Johnson (2008, page 56) concluded:

> ***Whatever is driving PC1 … it is in large part coming from areas of high human population, in absence of poultry***

Defendants' expert, Dr. Jarman (2008) documented contributions of P and fecal indicator bacteria to the IRW as permitted discharges from WWTPs, accidental bypasses/overflow releases, and land application of biosolids. He also provided data illustrating a poor history of responsiveness by Oklahoma regulatory agencies in dealing with violations by point sources which caused contributions of these constituents to surface waters in the IRW. The importance of point source contributions of nutrients to streams in the IRW have been well recognized at least since the 1980s (Jarman, December 2008). Plaintiffs' consultants have under-emphasized the continued importance of point source contribution in this watershed, by failing to recognize the clear association of P concentrations in streams within the watershed with locations of WWTPs, selectively deleting (without properly clarifying the effects of this action on key conclusions) from some of their analyses sites that were downstream from WWTPs (Dr. Engel, 2008), and choosing a human per capita P production rate at the lower end of available estimates (Ms. Smith and Dr. Engel, as per Figure 8 in Jarman, 2008).

Phosphorus concentrations in WWTP effluent were higher in the past than they are currently because of more recent P limitations placed on effluent and because of the elimination of phosphate laundry detergent. The manufacture of phosphate detergent for household laundry was ended voluntarily by the industry in about 1994 after many states, including Arkansas, had established state-wide phosphate detergent bans (Litke, 1999). After WW II, powdered clothes washing detergents were about 15% P by weight. In 1970, the industry limited the P content to 8.7% by weight in response to national concerns about eutrophication. In 1971, five cities in Illinois limited P-containing laundry detergents. The number of states having phosphate detergent bans increased steadily after 1971, up to 26 states by 1995. During the 1940s, the total P concentrations in raw household waste water effluent averaged about 3 mg/L, increasing to about 11 mg/L at the height of phosphate detergent use about 1970, and have since declined to about 5 mg/L (Litke, 1999).

Although substantial progress has been made in reducing point source contributions of P to streams in the IRW, it is likely that many of the improvements are only recently having an influence on water quality. In the mid-1990s, Arkansas and Oklahoma state agencies and cities agreed to consider methods to reduce P inputs by 40%, and P limitations were placed on WWTPs in the IRW (Jarman, December, 2008). However, for most treatment plants, these changes were not fully implemented until about 2003, and some still do not have discharge limitations (Jarman, December 2008). Therefore, the influence of these point source reductions may not be evident in much of the available water quality data for this watershed, especially the data collected prior to about 2003. Defendants' expert, Dr. Jarman reported approximately a 40% decline in P contribution in WWTP effluent in the IRW between the period 1997 -2003 and the period 2004-2007. This decrease corresponded with approximately a 40% decline in the concentration of P in base flow stream water in the Illinois River at Tahlequah, near the upper end of Lake Tenkiller (Connolly 2008).

Despite these substantial improvements in P contribution from WWTP point sources to streams in the IRW, even for the WWTPs that do now have more stringent P limitations, these limitations of 1 or 2 mg/L of TP in the effluent are still 27 to 54 times higher than the 0.037 mg/L standard for the Scenic River sections of the stream system in the IRW.

Nelson et al. (2003) estimated P loads and concentrations in the Illinois River at the Highway 59 bridge crossing in Arkansas, near the Oklahoma state line, and compared them with loads and concentrations estimated for five other streams. They found that their estimates of base flow concentrations of total P for five of the six watersheds (all except Moores Creek) were similar (near 0.25 mg/L), and stated:

> ***This is a possible confirmation that the base- flow concentrations are effected by wastewater treatment plant discharges, as Moores Creek is the only watershed without a permitted WWTP discharge.***

The WWTPs in Springdale, Fayetteville, Siloam Springs and Rogers have all agreed to reduce effluent total P concentrations to less than 1 mg/L (Ekka et al. 2006). Nevertheless, this voluntary reduction, if fully implemented, will still allow effluent discharged from these facilities into IRW streams to contain total P that is 27 times higher than the 0.037 mg/L standard.

WWTPs are not the only potential municipal sewage point sources of nutrients and fecal indicator bacteria to streams within the IRW. Jarman (2008) documented problems associated with the Watts total retention (lagoon) waste water treatment facility, which is situated within a quarter of a mile of the main stem Illinois River in Oklahoma, adjacent to the Arkansas state line. Although there is no effluent discharge from this sewage treatment facility, there is still the risk of pollution contributions to the river due to land application of treated sewage. The land application area associated with this facility is located within about 100 feet of the river. The U.S. Fish and Wildlife Service (USFWS) expressed concerns over a proposal for the Watts facility to begin taking waste water from the city of West Siloam Springs. The USFWS concern centered on application of treated waste water to hydric soils in the flood plain of the Illinois River. Jarman (2008) reported an accidental release of 275,000 gallons of treated waste water from the facility in 1999, which resulted in assessment of a $20,000 penalty by ODEQ. An assessment prior to this accidental release by Enercon Services, Inc, in a study commissioned by the Oklahoma Attorney General and the OSRC, concluded that:

> ***its proximity to the River and the presence of numerous pathways virtually assures that the Illinois River will be the target of and ultimate recipient of the contaminants associated with the Watts lagoon. (**cited in Jarman 2008**)***

It is important to note that, even though municipal sewage treatment facilities, such as WWTPs and the Watts lagoon, constitute an overwhelmingly important source of nutrients to stream water, they are not the only important sources of NPS water pollution associated with urban development. Runoff from urban areas also is well known to contribute substantial amounts of fecal indicator bacteria, nutrients, sediment, and other constituents to drainage water. Urban sources of these constituents can include fertilizer use on lawns and parks, pet and urban wildlife waste, erosion associated with construction activities, and broken or leaking sewer pipes.

Urban areas contain relatively high proportions of impervious land (i.e., parking lots, compacted soils on construction sites, roofs, roads, sidewalks, etc.), from which contaminants of all kinds can be rapidly flushed to streams during rain storms. Urban areas are specifically designed so as to move rain water quickly and efficiently to streams in order to prevent flooding. This is typically done via installation of extensive systems of storm drains, gutters, and roadside ditches. An unfortunate effect of such rapid routing of runoff into streams within urban areas is that there is much less opportunity for constituents such as P and fecal indicator bacteria, which tend to be removed from infiltrating water and retained on soils, to be removed from the runoff before it enters a stream. In urban areas, less water is routed through soils; more water is routed overland. As a consequence, proportionately more P and bacteria are carried from the land into the stream. This concept is not new; it is not specific to the IRW. Rather, it is a well-known facet of NPS pollution science. It was ignored by the Plaintiffs' consultants in this case.

Novotny (1995, page 23) concluded that urbanization is probably the greatest source of NPS pollution to streams. Nevertheless, it was not considered by Plaintiffs' consultants in targeting their sampling or interpreting much of their resulting data. Urbanization changes the hydrology of the watershed to favor transport of pollutants from the land surface to streams. Lawn fertilizers, pet waste, and urban wildlife waste are flushed into storm drains, bypassing the soils that might otherwise adsorb some of the contaminants present in that water. Soil loss to erosion from construction sites can reach magnitudes of over 100 tons per hectare per year. For that reason, construction occurring in only a small percentage of the watershed can contribute a major portion of the sediment carried by streams in the watershed (Novotny 1995, page 25). This sediment contributes directly to elevated suspended solids and turbidity; it also carries P. Novotny (1995, page 24) cautioned that newly developing urban lands (which are very common in the IRW) should receive special attention in NPS assessment:

> ***this stage of land is characterized by the high production of suspended solids caused by erosion of unprotected exposed soil and soil piles…Extremely high pollutant loads are produced from construction sites if no erosion control practices are implemented. Therefore, in establishing pollutant loadings relative to land uses, one must determine first whether the area is fully developed or if it is a developing area and/or significant construction activities are taking place therein.***

Novotny's caution is especially relevant to NPS pollution in the IRW. As described in Section III.3 of this report and by Grip (2008), new construction is widespread in the IRW, and northwest Arkansas has been in recent years one of the fastest growing metropolitan areas in the United States.

With an increase in the amount of impervious surfaces in response to urbanization, the urban portions of the watershed become more hydrologically active. Runoff events carrying heavy pollutant loads become more common (Novotny, 1995, page 27). Pollutants that accumulate in the streets, parking lots, and areas of compressed soil are readily transported in surface runoff. These pollutants can include dust and soil particles (which can be high in P content), animal waste, atmospherically deposited nutrients, and fertilizers. High-density urban zones are nearly completely impervious and have very limited capacity to attenuate pollution, with almost all emitted pollutants eventually reaching surface waters (Novotny and Olem 1994, page 493). Novotny (1995, page 45), based on EPA's Nationwide Urban Runoff Project (NURP), estimated that the event mean concentration of TP in urban runoff for the median urban site was 0.37 to 0.47 mg/L, with the 90th percentile urban site yielding an event mean concentration of TP equal to 0.78 to 0.99 mg/L. The TP in urban runoff would be expected to be partly from erosion and partly from other P contributions associated with such factors as fertilizer use, pet waste, leaking or faulty sewer lines, urban wildlife, and other sources.

Data from EPA's National Urban Runoff Program (U.S. EPA, 1983) found that the median urban stream site in the United States received storm runoff having total P concentration of 0.37 (10 times higher than the Illinois River standard) to 0.47 mg/L, with 10% of values more than twice as high (Novotny 1995, page 61). EPA (1983) further concluded that:

> ***Fecal coliform counts in urban runoff are typically in the tens to hundreds of thousand per 100 ml during warm weather conditions, with the median for all sites being around 21,000/100ml.***

For comparison, the median concentration of fecal coliform bacteria in streams sampled in the IRW by Plaintiffs' consultants in areas representing a variety of land uses and reported in Dr. Olsen's database was 130 cfu/100 ml.

It has been previously shown that nutrient exports from urban watersheds can be as high, or higher, than exports from agricultural lands. For example Osborne and Wiley (1988) investigated land use and stream water quality in the Salt Fork watershed in Illinois, which is primarily (90%) agricultural. Urban areas accounted for 5% of the total watershed areas, which (as in the IRW) was concentrated in the upper watershed. They found that:

> ***Despite the over-riding dominance of agricultural land use within the Salt Fork watershed, our results demonstrate that urbanization rather than agriculture has the greatest impact on stream SRP concentrations.***

The Illinois River Management Plan (OSRC, OSU, and NPS, 1999) concluded that:

> ***Urban runoff is recognized as one of the major non-point sources of pollutants within watersheds. The Illinois River Corridor is a mixture of moderately populated urban areas with a large growing suburban and rural population.***

Urban land use has also been associated with negative impacts on stream biological integrity. For example, Wang et al. (1997) found that urban impacts on stream biological integrity in Wisconsin became severe when the percent of the watershed covered by urban land use exceeded 10% to 20%. Effects have been associated with the amount of impervious surface area, amount of developed land, and population density (Klein 1979, Benke et al. 1981, Jones and Clark 1987, Lenat and Crawford 1994).

Parsons and University of Arkansas (2004) characterized water quality and aquatic biological resources of several streams in the IRW. The objective was to provide data to U.S. EPA for use in evaluating potential 303(d) listings of water quality impairment for Arkansas. They concluded that multiple stressors are affecting this system at all times. Water chemistry nutrient results at locations downstream from WWTPs were nearly always higher in nutrient concentrations than the respective upstream location. Of the 12 sites assessed in the IRW for this study, one was classified as "severely impacted" and two were classified as "impacted" on the basis of multiple chemical and biological indicators of environmental health. The severely impacted site was located on Spring Creek below the Springdale WWTP. One of the impacted sites was located on Muddy Fork below the Prairie Grove WWTP. The other impacted site was located on Osage Creek, below urban development and multiple WWTP discharge locations.

According to data compiled for this case by Defendants' expert, Dr. Ron Jarman, WWTP effluent within the IRW usually contains about 10 to 40 cfu/100 ml, on average, of FCB. Nevertheless, effluent discharged directly into the Illinois River system sometimes contains levels that exceed the 200 cfu/100 ml Primary Body Contact Recreation standard, including values in the thousands of cfu per 100 ml. Such values of bacteria in the effluent from WWTPs contribute to the overall bacterial concentrations in the streams within the watershed.

Routine operation of WWTP facilities contributes well known point sources of P and fecal indicator bacteria. In addition to these routine contributions, there are numerous accidental releases of these constituents to the stream system. The accidental release of raw or partially treated sewage is not an unusual event in the collection system of a WWTP. This can introduce large amounts of nutrients and fecal indicator bacteria to stream waters. Jarman (2008) noted that there are many causes for these events, including line breakage, blocking or plugging of the lines, construction damage, heavy rainfall, and system breakdowns at a lift station or the WWTP. Such events represent a recurring source of nutrients and fecal bacteria in urban settings.

Dr. Jarman documented sewage bypasses (uncontrolled discharge of untreated or partially treated sewage) within the watershed over a period of seven years. Although data were not available from all townships within the watershed, and data were only available for some years in others, Dr. Jarman reported about 700 hours of sewage bypass with average concentrations of FCB in the range of 1.5×10^{15} (one and a half thousand trillion) or higher per bypass event (Table 5-2). Most of these bypasses involved raw sewage, in volumes that averaged 500 gallons (Westville) to 9,060 gallons (Lincoln). I have become aware of additional bypass data that were not included in Table 5-2, indicating two bypasses from the Stilwell facility comprised of 1 million and 800,000 gallons of raw sewage. These bypasses data were discussed by Dr. Madden in his September, 2008 deposition for this case (Madden 2008, deposition transcript, pages 61 to 71). Thus, sewage bypasses constitute an important additional source of fecal bacteria to stream water in this watershed.

Mixed land use watersheds often have mainly forests in the upper reaches, and urban and agricultural land uses in the lower reaches. Therefore, contaminants that might be contributed to the streams from humans and their activities and their livestock often increase in a downstream direction, from the headwaters to the larger streams that are found downstream. The IRW is fairly unusual in that urban development is concentrated mainly within the headwater areas of the watershed (See Figure 3-1). For that reason, stream waters in the IRW tend to have relatively high concentrations of P and fecal indicator bacteria even within the upper stream reaches. This makes it difficult to evaluate the relative importance of different sources of contaminants found in the non-urban areas in this watershed. The Comprehensive Basin Management Plan for the IRW (Haraughty 1999, page 30) correctly identified that:

> ***…much of the phosphorus comes from the headwaters of the watershed, thus remediation efforts should concentrate in this area.***

Stream water data collected by Plaintiffs' consultants for this case clearly show the dominant influence of urban areas in general, and WWTPs in particular, on stream total P concentrations and to a lesser extent stream *E. coli* concentrations. Figure 5-5 illustrates the spatial patterns in total P concentrations in the IRW during low flow conditions, based on the geomean of 5 or more samples calculated from Dr. Olsen's database. The same pattern is seen for Dr. Olsen's data when samples collected under all flow regimes are included (Figure 5-6).

The water quality standard for P in the IRW is frequently exceeded even under low flow conditions (Figure 5-5), at times when NPS pollution associated with activities on pasture lands would not be expected to contribute appreciably to stream water quality. Such exceedances of the P water quality standard during low flow are probably caused primarily by point sources of pollution, mainly waste water treatment plant discharge from municipalities, directly into streams within the watershed. All of the low flow geomean P values that were relatively high were based on samples collected downstream from a developed area and downstream from a WWTP.

Dr. Olsen's database contains fewer samples analyzed for *E. coli*, so for those maps the criterion was relaxed to include all sites for which there were at least three (rather than 5) samples on which to base the geomean calculation. Geomean *E. coli* results for base flow and for all flow conditions are shown in Figures 5-7 and 5-8, respectively. Although there are fewer sample locations that met the criterion for number of samples, the patterns are similar. Again, the highest geomean concentrations tend to be located downstream from urban areas and WWTPs.

Thus, with nearly 300,000 people living in the IRW, mostly in urban areas in the upper watershed, there are clearly substantial sources of fecal indicator bacteria and nutrients to streams that flow through these urban areas. Plaintiffs' own data show this. The scientific literature shows this. Attempts to place most of the blame on land application of poultry litter (or any other source in the non-urban portions of this watershed) simply makes no sense.

6. Within non-urban areas in the IRW, there are many potential sources of P and fecal indicator bacteria to stream waters.

In addition to urban sources of NPS pollutants to streams in the IRW, described above, there are also multiple potential sources of P and fecal indicator bacteria to stream waters within the non-urban portions of the watershed. Plaintiffs' consultants **assume** that poultry litter application is the only, or the dominant, source in non-urban areas. They do not adequately assess the importance of the other potential sources. These other potential sources include, in particular, cattle manure, septic systems, roads and associated ditches and culverts, and other livestock and wildlife. Plaintiffs' consultants largely ignore or dismiss these other well-known potential sources of NPS pollution.

Cattle Manure

Cattle grazing is well known to be an important source of NPS pollutants to streams (Clark et al. 1999). In view of the large number of cattle in the IRW (Clay 2008), the importance of cattle as contributors of P and fecal indicator bacteria to streams in the IRW must be evaluated in any credible assessment of NPS pollution. Plaintiffs' consultants did not perform such an evaluation. Rather, they assumed that cattle could not be major contributors to NPS pollution because cattle consume forage, which contains P, and then excrete it within the pasture system. Thus, Plaintiffs' consultants conclude that cattle do not bring new P into the watershed, and therefore that they cannot be responsible for transport of P and fecal indicator bacteria to the stream system. This line of reasoning is flawed because it totally ignores the importance of transport processes and the tendency of cattle to transfer, via their grazing and movement patterns and access to streams, P and fecal indicator bacteria from the upland pasture areas to the stream itself or to the riparian zone adjacent to the stream, from which these constituents can much more readily be transported to stream water during a rain storm. This process is more fully explained in Sections III.11 and III.9 of this report. There are approximately 200,000 cattle, calves and milk cows in the IRW, based on agricultural census data compiled and provided to me by Dr. Billy Clay (pers. comm. 2008). I have observed that these animals commonly have access to streams and stream banks in the IRW. Clearly, they defecate directly into surface water, or defecate on land immediately adjacent to surface water (Clay 2008). Thus, fecal matter from livestock is both directly deposited into streams and is deposited to riparian zones where it is highly susceptible to surface transport from land to stream during rainstorms. In contrast, fecal matter in poultry litter, when the litter is properly applied, is not deposited in, or in proximity to, surface water or in areas that are likely to generate saturated overland flow from the pasture surface to the stream.

Cattle are widely distributed throughout the IRW, although the densest concentrations occur in proximity to the urban areas in the upper reaches (eastern portion) of the watershed (Figure 6-1). Because these livestock are so numerous and widely distributed, and because they occur in and immediately adjacent to streams in some areas, they cannot be ignored in evaluating fecal indicator bacteria and nutrient source issues in this watershed. The failure of Plaintiffs' consultants to fully consider the potential effects of cattle on the concentrations of P and fecal indicator bacteria in streams represents a major flaw in their analyses of water quality in the IRW.

Livestock pastures are well known sources of NPS stream pollution. Dismissal by Plaintiffs' consultants of the importance of cattle to NPS issues in the IRW is not consistent with the position taken by the Illinois River Management Plan (OSRC, OSU, and NPS 1999). The Management Plan concluded that:

> ***Unconfined livestock in the Illinois River Corridor have directly affected stream and riparian habitats. Removal of vegetation, trampling of streambanks and wading in shallow streambed areas has led to bank instability, increased erosion and sedimentation, and alteration of habitat.***

Plaintiffs' consultant, Dr. Berton Fisher, did not evaluate the extent to which cattle serve as a transport mechanism for taking P that was contained in living pasture grass and transporting it into or near water courses, although he acknowledged that cattle:

> ***can assist in that process.*** (September 4, 2008 deposition testimony, page 450-451)

Often, it is not the grazing intensity on the land that determines the extent of stream water pollution associated with cattle; rather, it is the unrestricted access of cattle to water that has the major impact (Novotny, 1995, page 23). I have observed that cattle in the IRW commonly have access to streams, and that cattle access to streams appears to be more widespread on the smaller tributaries than it is along the main stem Illinois River.

It has been reported in the scientific literature that P concentrations in runoff from intensively managed dairy pasture can be as high as 7.36 mg/L (Nash and Murdoch 1997, cited in Haygarth and Jarvis 1999). Previous studies have found increased concentrations of nutrients in streams draining pasture land; for example, pasture in the Ozarks Highlands region of Missouri is associated with increased stream concentrations of nutrients, suspended solids and algal levels relative to forested areas (Perkins et al. 1998).

Cattle grazing in riparian areas can cause erosion and movement of P into stream waters. Butler et al. (2006) found that vegetative ground cover has a large impact on the volume of surface runoff and P export from pastured riparian areas. Riparian areas with bare ground contributed substantial amounts of sediment and P to surface waters during heavy rainfall.

Plaintiffs' consultant, Dr. Fisher, testified in his deposition (September 4, 2008) about an email that he received from Shannon Phillips from the Oklahoma Conservation Commission (labeled as Exhibit 27) which documented:

> ***elevated nutrient concentrations and dramatic increases in periphyton growth***

attributed by Ms. Phillips to cattle grazing in Cedar Hollow, a subwatershed of the IRW which was believed to not have received land application of poultry litter.

Dr. Olsen testified in the Preliminary Injunction hearing that he could discriminate among poultry, WWTP, and cattle as sources of constituents in water in the IRW, but he did not articulate a specific criterion (such as his principal component (PC) 1equal to or greater than 1.3 cutoff that he used to determine poultry impact) to assign a water sample to the cattle impact category. Dr. Glenn Johnson (2008, pages 40 to 50) describes in detail how Dr. Olsen's arguments changed from the Preliminary Injunction stage of this case to his September, 2008 deposition. As Dr. Johnson shows, all four of Dr. Olsen's cattle-impacted samples had PC1 greater than 1.3, above his unique poultry waste signature threshold, and Dr. Olsen was unable to obtain separation in his PCA analyses between cattle and poultry impact. When confronted with new evidence regarding PCA results for samples that Dr. Olsen believed to be cattle impacted, his opinion that cattle are not an important source in the IRW never changed, only the line of reasoning that he needed to adopt to reach that conclusion. In the final analysis, it appears that Dr. Olsen believes that cattle cannot be important sources of constituents to stream water because he is unable to see a strong signal in his PCA. As described in Section III.12 and in the expert reports of Dr. Glenn Johnson, Dr. Larson, and Dr. Chadwick, Dr. Olsen's PCA is not a scientifically legitimate tool for excluding cattle, or any other potentially important nonpoint source, as significant in this watershed.

I located 11 bacterial TMDL reports that were completed for the Oklahoma DEQ and that provided an estimate of what constituted the most important source of fecal bacteria to the subject watersheds. The locations of the watersheds for which those TMDL reports have been completed are shown in Figure 6-2. Together, they cover much of the state of Oklahoma, including watersheds to the north and south of the IRW, including areas of intensive poultry farming. Four of the 11 TMDL reports (Boggy Creek, North Canadian River, Lower Red River, and Little River) stated that livestock was estimated to constitute the largest contributor of fecal coliform bacteria loading to land surfaces AND that cattle appeared to be the most likely livestock source of fecal bacteria to streams. All of the remaining 7 TMDL reports stated that cattle appear to represent the most likely or largest source of fecal bacteria. Thus, there are 11 TMDL reports completed for the state of Oklahoma, of which I am aware, that single out one source of fecal bacteria as being most important. **All** of those single out cattle. If cattle represent the major source of fecal indicator bacteria in these watersheds, it is logical to assume that they may also represent an important source of P. It therefore seems curious that Plaintiffs' consultants dismiss the importance of cattle in the IRW based on the weak argument that cattle merely recycle P already present within the watershed (See detailed discussion of this issue in Section III.17 of this report) and Dr. Olsen's inability to find a strong signal for cattle waste in his PCA analysis (See discussion of the numerous problems with Dr. Olsen's PCA in Section III.12). In fact, the density of cattle in the IRW is generally equal to, or greater than, the densities of cattle in these 11 Oklahoma watersheds for which TMDL analyses suggested cattle as being recognized as the most likely source of fecal indicator bacteria (Figure 6-3).

Not only are cattle known to be important sources of NPS pollution to streams, but in addition, reducing the amount of time that cattle spend in streams and riparian zones via installation of off-stream watering sources has been shown to dramatically decrease bank erosion and improve stream water quality in cattle-impacted streams. For example, Sheffield et al. (1997) installed a watering trough and subsequently documented decreased cattle use of the adjacent stream in Virginia. Stream bank erosion was reduced by 77%. Flow-weighed total P concentration in the stream outlet decreased from 0.2 mg/L to 0.07 mg/L, a decrease of 65%. Total suspended solids were reduced by 89%. Fecal coliform bacteria concentration was reduced by 51%. Similarly, in a study of BMP effectiveness on dairy farms in Oregon, Sullivan et al. (2004) demonstrated a reduction by about 74% in FCB concentrations in stream water for a stream that passes through pasture land subsequent to installation of best management practices that included riparian fencing and off-stream watering for cattle. Plaintiffs' consultants contend that cattle are not important contributors of fecal indicator bacteria and other constituents to streams because they merely recycle nutrients that are already present on pasture land. If this was true, it would not be possible to improve water quality conditions via improved cattle management. Improved cattle management, via BMP installations, is a major focus of watershed restoration work nationwide. Federal and state governments and stakeholder groups spend considerable resources on these efforts. The reasons for this are simple: cattle are important contributors of NPS water pollution; improved cattle management contributes to improved water quality. It seems unbelievable to me that Plaintiffs' consultants do not understand this.

<u>Septic Systems</u>

Septic systems are often considered to be one of the most common and significant sources of stream pollution in rural residential areas (Novotny and Olem, 1994, page 483). Stream pollution from septic systems is primarily due to two pathways: 1) subsurface transport of mobile pollutants such as nitrate via shallow discharge of aquifers into the receiving water, mostly during base flow, and 2) movement of septic effluent to the ground surface when the septic system is not functioning properly (Novotny and Olem, 1994, page 483).

My analyses suggest that approximately 76,000 (Table 4-1) people in the IRW live in communities that do not have central waste water treatment facilities. These people can be assumed to have septic systems for disposal of their household waste water. An unknown percentage of these septic systems are not adequate to protect surface water quality.

According to the Illinois River Basin Plan (Haraughty 1999), constructed by the Oklahoma Conservation Commission for the portions of the IRW that lie within Oklahoma, up to 75% of the septic systems in portions of the IRW may be inadequately constructed or situated. In addition, Engineering Services, Inc. (2004) reported results of septic system surveys in Tontitown and Highfill, Arkansas. They found that 43% of surveyed septic systems in Highfill and an unknown percentage in Tontitown had reported failures, including surfacing sewage, sewage backup, and surface discharge of gray water. Less than 30% of the septic systems had valid permits.

Thus, there is reasonable basis for assuming that an appreciable percentage of the septic systems that serve roughly 76,000 inhabitants of the IRW have some problems associated with their operation or location. As a consequence, it is probable that septic systems can contribute substantial amounts of P and fecal indicator bacteria to streams in the watershed. This source of P and fecal indicator bacteria to streams in the IRW was not fully considered by Plaintiffs' consultants in this case. In addition, Plaintiffs' consultants did not collect any samples in the IRW that were intended to shed light on movement of P, fecal indicator bacteria, or other constituents from septic systems into streams within the watershed.

Bacterial TMDL analyses conducted for ODEQ routinely include an assessment of septic system contribution to overall bacterial loads to rivers in Oklahoma that are 303(d) listed for fecal indicator bacteria. These include the following TMDL reports:

- Canadian River (Parsons 2006b, 2008d)
- North Canadian River and Shell Creek (Parsons 2006a)
- Lower Red River (Parsons 2007c)
- Neosho River (Parsons 2008c)
- Washita River (Parsons 2007a)
- Little River (Parsons 2007d)
- Arkansas River Segments and Haikey Creek (Indian Nations Council of Governments 2008)
- Sans Bois Creek (Parsons 2008a)
- Boggy Creek (Parsons 2007b)
- Upper Red River (Parsons 2008b)

Plaintiffs' consultants did not conduct any analyses to determine the potential impacts of septic systems in the IRW. Dr. Fisher acknowledged in his September 4, 2008 deposition (pages 513-514) that such an effort was not part of his analysis in this case.

Given the rather routine inclusion of potential septic system contributions of fecal indicator bacteria to streams as part of the TMDL process conducted for ODEQ in watersheds throughout Oklahoma, an assessment of nonpoint sources within the IRW should include an evaluation of the potential importance of septic systems as sources of NPS pollutants in this watershed. Such an evaluation was not conducted by Plaintiffs' consultants in this case.

Plaintiffs' consultant, Dr. Engel, actually found a significant relationship between the presence of septic systems and stream P concentration in his analyses of a set of comparative subwatersheds. He dismissed, without any reasonable basis, the relevance of this finding as an artifact of the cross-correlation between poultry house density and septic system distribution. In fact, he could have just as easily dismissed the relevance of his correlation between poultry house density and stream P concentration as an artifact of the same cross correlation. See further discussion of this issue in Section III.8 of this report. In Dr. Engel's Appendix G, he presents less than two pages of analysis that provide the foundation for his dismissal of his observed strong correlations between septic system density and stream P concentrations in his high flow basins in the IRW. He states that:

> ***The Oklahoma Department of Environmental Quality (1997) investigation of septic systems in the Illinois River concludes "systems identified in this study were found to pose no apparent threat to the quality of the Illinois River."***

Examination of that ODEQ (1997) report yields a very different picture than was presented by Dr. Engel. First, the ODEQ (1997) report consists of only six pages of text, some site maps, and tables; it includes no in-depth analysis of anything. Second, the study did not investigate residential septic systems (except where multiple residences used the same system); rather, it focused on 59 non-residential septic systems (i.e., schools, stores, taverns, etc), three community waste water treatment plants, and eight pit privies. Data were collected over a two-week period in July 1997 by interviewing system owners/operators. No field data were collected: no water samples, no runoff evaluation, no evaluation of possible system malfunctions, no determination of stream water quality in proximity to the sites included in the study. Not one of the tens of thousands of individual residential septic systems in the IRW was included. Data were collected by interview; such data included the type of system, type of use, number of users, etc. Distances between each of the 59 systems studied and the nearest stream were calculated. ODEQ's estimates of probable flow in these non-residential systems were generally low, and the systems evaluated were mostly located a fair distance from the nearest stream. On this basis, ODEQ (1997) concluded that these investigated systems posed no apparent significant threat. No conclusions were drawn by ODEQ regarding any potential threat from the tens of thousands of individual residential septic systems in the IRW, either individually or collectively. Dr Engel's contention that this study provides adequate basis for his dismissal of the importance of septic systems in the IRW is without merit.

Dr. Engel also attempted (page G-1 of his expert report) to evaluate P load from septic systems in his 14 study subwatersheds, and claimed that his calculations showed that P load in the small study streams exceeded P loads from the residential septic systems in those watersheds. Even if his calculations are correct, this reveals nothing about the importance of septic systems watershed-wide in the IRW. Furthermore, Dr. Engel appears to not understand that the overall load within the watershed does not determine the extent of possible stream contamination; pathways for pollutant transport must also be considered, and were not considered by Dr Engel in his inadequate assessment of the potential for septic systems to contribute pollutants to streams in the IRW. Furthermore, it is not reasonable to assume that there is one primary source of P contribution to streams in this watershed, given the mix of land uses and large numbers of people and animals. Plaintiffs' consultants' apparent search for evidence that might incriminate one source type is not defensible. There are many source types; each is widely distributed; the relative importance of sources in one area is not necessarily the same as the relative importance in other areas. In his Appendix G, Dr. Engels concludes:

> ***Based on this analysis and the Oklahoma Department of Environmental Quality report on septic systems [*discussed above*], the septic systems in the high flow watersheds are not the primary source of P exports in runoff and baseflow.***

Again, Dr. Engel's search for the "primary source of P exports" is conceptually flawed before he begins his analyses.

As detailed above, Dr. Engel provides little information that would actually help in a determination of how important septic systems are to P contributions to streams throughout the watershed. The ODEQ study contributes no useful information for addressing this question. The loads calculations offered by Dr. Engel ignore the importance of transport from source location to stream, the diversity of conditions across the landscape, the large number of septic systems that occur in the IRW, and the overwhelming likelihood that a great many NPS sources (rather than one "primary" source) are involved in contributing P to stream waters in the IRW.

<u>Erosion</u>

It has been well recognized for more than 25 years that erosion is an important source of NPS water pollution. Novotny (1980) stated:

> ***Since a major portion of nonpoint pollution is associated with sediment, understanding the process of erosion and sediment movement and deposition is important.***

Nevertheless, Plaintiffs' consultants did not undertake a study of erosion and erosion sources of P in the IRW. Plaintiffs' consultants' collection and analysis of sediment cores from Lake Tenkiller is insufficient as a basis for quantification of watershed sources of P associated with erosion. This is, in part, because sediment is retained at multiple locations throughout the watershed. The failure of Plaintiffs' consultants to conduct an assessment of erosion and associated P is a substantial oversight, given the extensive amount of construction-related land clearing actions within the watershed in recent years, as well as the extensive network of roads and the access to streams of large numbers of cattle, which trample vegetation and thereby cause erosion from riparian areas. All of these are issues and actions that would be expected to accelerate erosion within the watershed. None of them were adequately addressed by Plaintiffs' consultants in their sampling program or interpretation of data.

Erosion is a common and well known source of P to stream water. Erosion is not specific to urban or to agricultural land, but rather occurs watershed-wide. Nevertheless, there are certain types of land use that tend to promote higher levels of erosion than others. These are the land uses that disturb soils and remove vegetative cover.

Suspended sediment loads of many rivers have increased up to 10-fold as a result of land use changes in the watershed (Novotny 1995, p. 112) . The activities that cause the most disturbance, and therefore the highest amount of erosion, are generally known to include deforestation, construction site erosion, and intensive agriculture (including row crops and high concentrations of livestock in feedlots or on pasture lands) on highly erodible lands (Clark 1985, Novotny 1995,

p. 112). Among the various environmental effects of increased erosion is the fact that sediment carries nutrients, including P, and metals. Large amounts of sediment in stream waters originate from urban areas (Novotny 1995, p. 114). Sediment yields from urban developing areas can be very high, reaching values up to 50,000 tons of sediment per square km per year (Novotny 1980, 1995, page 115).

It has long been recognized that movement of P from the land to stream water is often caused largely by erosion (Smith et al. 2001, Weld et al. 2001). Erosion can be associated with any land disturbing activity within the watershed. All land disturbing activities can therefore result in the addition of sediment to streams. In a study of North Carolina streams, construction activities caused the highest erosion rates (Lenat and Crawford 1994). Erosion is also often strongly associated with the presence of roads, especially dirt roads, and the ditches and culverts that are found along and across roads. Land clearing activities, including logging, road building, and row-crop agriculture, have long been known to be important sources of sediment to streams (cf., Birch et al. 1980). Such erosion-causing activities can result in substantial contributions of P to drainage water (Hobbie and Likens 1973, Birch et al. 1980, Sullivan et al. 1998a, Sullivan et al. 1998b). For example, Hobbie and Likens (1973) found a 12-fold increase in P flux in a deforested watershed compared with its control. Cattle and other livestock that are permitted uncontrolled access to riparian areas cause sloughing of stream bank soils and elimination of stream bank vegetation (Novotny and Olem 1994, page 683). Pastureland becomes a source of NPS pollution when proper erosion control practices are not in place or when livestock are allowed to approach or enter surface waters. Overgrazing and permitting livestock to approach and enter water courses are major polluting activities on pastures and rangelands. Novotny and Olem (1994, page 686) concluded that, if such activities are controlled, pollution from pastures and rangelands may be minimal.

There are 5,169 miles of road in the IRW, 54% in Arkansas and 46% in Oklahoma, based on U.S. Census data for 2000. Of the roads in the IRW within Arkansas, about 52% are paved and the remainder are dirt, gravel, or otherwise unimproved roads (U.S. Dept. Commerce, Census TIGER files for the year 2000). Dirt roads generally contribute more erosion than do paved roads. The unpaved roads, in particular, can be important sources of erosion to streams, and that erosion can carry large quantities of P. In some watersheds, erosion from roads and other disturbances can constitute the dominant source of total P in streams (Sullivan et al. 1998a,b).

Roads in the IRW contribute an unknown amount of sediment-associated P to streams. In addition, because of the impervious nature of road surfaces, they can undoubtedly be effective vehicles of transport to streams for fecal indicator bacteria deposited on the road surface. Plaintiffs' consultants did not assess the importance of roads, or of other important erosion sources, as potential contributors of NPS pollutants to streams in the IRW.

In addition to erosion from construction sites, roads, and associated ditches and culverts, stream bank erosion can be an important source of sediment to streams, along with its accompanying P load. Stream bank erosion is typically dependent on soil characteristics and the extent to which riparian vegetation is disturbed. Trees and some species of shrubs and herbaceous plants tend to have extensive root systems that help maintain the integrity of the stream bank and limit bank erosion. Cattle grazing in the riparian zone, which is prevalent in the IRW, reduces the vegetative cover, thereby increasing the potential for bank erosion to occur. The Oklahoma Conservation Commission's Comprehensive Basin Management Plan for portions of the IRW within

Oklahoma (Haraughty 1999, page xi) recognized the importance of this issue, and concluded that:

> ***Bank erosion along the Illinois River and its tributaries poses a substantial threat to the system. Eroding banks provide sediment, gravel, and nutrients which destroy valuable land, degrade water quality, destroy critical aquatic habitat, and eventually fill in Lake Tenkiller. This bank erosion is often caused by elimination or poor maintenance of the riparian zone, bridge construction, upstream or downstream changes in channel morphology and/or various upstream land use changes. Estimates of the loading from the bank material suggest that eroding banks contribute a significant amount of the total nutrient load in streams…***

This conclusion was based on evaluation of several sources of data on bank erosion in the IRW, including characterization of selected stream bank areas, estimation of long-term erosion from aerial photographs, and results of a short-term bank erosion study. It was estimated that, overall, the Illinois River became an average of 18% wider between 1979 and 1991, as a consequence of bank erosion. Haraughty (1999, page 44) estimated that 3.5 million tons (62 million cubic feet) of material was eroded into the river from the stream bank between 1979 and 1991. The Baron Fork once sustained a canoe float industry, but has become too shallow to canoe as a consequence of erosion (Haraughty 1999, page 101). Given the importance of erosion in the IRW, and the fact that its importance is well-recognized and described in the OCC's Comprehensive Basin Management Plan, it is improper that Plaintiffs' consultants would ignore this issue in formulating their sampling plan and in interpreting NPS issues in this watershed.

Grip (2009) also provided estimates of bank erosion along a 59-mile stretch of the Illinois River from Lake Frances to Lake Tenkiller. Grip (2009) estimated, based on examination of maps and aerial photographs, that over 15 million cubic yards of sediment have been relocated within this section of river since 1972. Grip (2009) stated that he would expect that only a fraction of that eroded sediment has reached Lake Tenkiller. Studies of sedimentation rate in Lake Tenkiller would be expected to only reflect a portion of the erosion contributed to the Illinois River and its tributaries; the balance would remain in the stream channels and various impoundments that exist in the watershed.

Novotny (1995, p. 115) concluded that the most important sources of erosion include land-disturbing agriculture (especially when spring rains fall on frozen soils), urban areas (especially exposed bare soils and street dust), road construction, logging, strip mining, and stream bank erosion (especially associated with loss of riparian vegetative cover). Neither poultry operations nor pasture lands were listed by Novotny (1995) as being among the most important sources of erosion, although livestock access to riparian zones and to stream channels adjacent to pastures can be important.

Erosion tends to transport primarily the fine particle (clay) and organic matter fractions of the soil from land to stream water. These can be relatively rich in P. Therefore, eroded soil is often enriched in P by a ratio of two or more as compared with particles that remain behind in the soil (Brady and Weil 1999, page 547).

Nutrient enrichment of lakes has been shown to result from NPS inputs associated with conversion of land from native cover to agriculture and urban land use (Stoermer et al. 1993, Schelske and Hodell 1995, Reavie and Smol 2001, Jones et al. 2004). Croplands have been shown to be particularly well correlated with nutrient concentrations in streams (Perkins et al.

1998) and reservoirs (Jones et al., 2004) in Missouri. For example, Jones et al. (2004) found that the percent cover of croplands explained 60% to 70% of the variation in the concentrations of total P and total N in Missouri reservoirs.

Novotny and Olem (1994, p. 247) concluded that general land disturbance by agriculture or construction can increase erosion by two or more orders of magnitude (factor of 100 or more). They further concluded that the highest rates of erosion typically result from deforestation, construction site erosion, and intensive agriculture on highly erodible lands (Novotny and Olem 1994, page 248).

The potential for soil erosion and associated nutrient export increases with soil disturbance (Pitois et al. 2001). Disturbed soils are more exposed to the weather and therefore prone to erosion. Erosion generally controls the movement of particulate P in landscapes (Sharpley et al. 1993). The particulate P movement on agricultural land is a complex function of rainfall, irrigation, runoff, and soil management factors that affect erosion.

Erosion associated with roads has been studied in Arkansas. For example, the Watershed Conservation Resource Center (2005) assessed the contribution of sediment from unpaved roads in three subwatersheds of the Strawberry River watershed in Arkansas, using the U.S. Forest Service Water Erosion Prediction Project modeling module. The study watersheds have a total area of 92 square miles. A survey was conducted of 10% of the publicly owned unpaved roads to determine slope, distance between water diversions, width, road characteristics, presence of ruts, presence of ditch vegetation, fill width, and fill grade. These variables provided inputs to the modeling effort, along with soil texture and rock content, climatic data, and traffic levels. The sediment loads from publicly and privately owned unpaved roads were estimated to be 1,500 tons and 1,412 tons (+/- 50%), for a total of 2,912 tons/yr. Averaged across all unpaved roads in the study area, the estimated sediment entering a stream was 18.8 tons per mile per year.

There are 80 miles of publicly owned and 64 miles of privately owned unpaved roads in the study area considered by the Watershed Conservation Resource Center (2005). The total unpaved road density is 1.6 miles of road per square mile. This compares with more than 1,300 miles of unpaved road in the Arkansas portion of the IRW, yielding an unpaved road density of 1.8 miles of unpaved road per square mile of watershed in the Arkansas portion of the IRW. Thus, the density of unpaved roads in the Arkansas portion of the IRW is slightly higher than is the density of unpaved roads in the portions of the Strawberry River watershed in Arkansas, for which it was estimated that nearly 19 tons of sediment enter the stream system through erosion each year for each mile of unpaved road.

Harmel et al. (1999) also recognized that bank erosion has introduced concern about resource conditions of the Illinois River. They conducted a study of a 101 km stretch of the river from Lake Frances to Lake Tenkiller to quantify erosion rates. Short-term erosion was measured with bank pins and cross-section surveys after four 2- to 2.5-year return period flow events between September 1996 and July 1997. The cumulative erosion from these four rain events averaged 1.4 meters. Long-term erosion was evaluated from aerial photographs taken in 1979 and 1991. Lateral erosion during that 12 year period averaged 16 m, or 1.4 m/yr on 132 eroding stream banks.

Other Potentially Important Sources

There are likely more than 200,000 large mammals (livestock and wild deer; Clay 2008) in the IRW, in addition to the approximately 200,000 cattle discussed above. These other livestock include, in particular, swine, horses, and sheep (Clay 2008). In some instances, these livestock have direct access to streams and riparian zones. In other instances, livestock manure is land applied (Clay 2008). The potential for these animals to contribute P and fecal indicator bacteria to streams in the IRW was not fully addressed by Plaintiffs' consultants.

Wildlife is a well-known contributor of NPS pollutants, especially fecal indicator bacteria, to streams. Myoda (2008) discusses the importance of wildlife as a bacterial source in the IRW.

Many species of wildlife preferentially utilize riparian or stream habitat, thereby increasing the likelihood that fecal material will be deposited in, or immediately adjacent to, streams. Plaintiffs' consultants did not fully consider the importance of wildlife as potential causes of fecal indicator bacteria above water quality standards in streams of the IRW.

Based on the affidavit and materials provided during the Preliminary Injunction hearing by Plaintiffs' consultant, Dr. Lowell Caneday (2008), there are approximately 155,500 recreationists per year on the Illinois River in Oklahoma. Although I make no attempt to verify or substantiate Dr. Caneday's estimate, there clearly are many recreationists using this river, especially during the summer recreation period, May through September. Toilet facilities have not been adequate to support such river use (Haraughty 1999), especially given the high estimate of the numbers of people who float the river (76% of total users) and are therefore away from developed facilities. The volume of human waste deposited along the river and the shores of Lake Tenkiller by these users, and the potential for such waste to contribute P and fecal indicator bacteria to the stream system was not evaluated by Plaintiffs' consultants for this case. Analyses reported by Defendants' expert, Dr. Jarman (2008) include findings of substantial recreational use within the watershed over a period of 40 years and resulting contribution of P and fecal bacteria.

Plaintiffs' consultants focused their attention on land application of poultry litter in the IRW, but largely ignored land application of swine manure, commercial fertilizer, and biosolids as potential sources of P and/or fecal indicator bacteria. There are about 166,000 swine in the watershed. This population represents a large quantity of fecal material which is probably land applied (Clay 2008), presumably partly in the watershed. Plaintiffs' consultants did not collect any samples or conduct any analyses in an attempt to determine the importance of any of these potential sources of land applied fecal materials and chemical fertilizers as contributors to stream water quality. I do not have information on the locations of land applied swine manure or commercial fertilizer in the IRW. Dr. Jarman determined the general locations of biosolids applications. Application areas generally correspond with locations of waste water treatment plants.

Lake Frances

Lake Frances is a man-made impoundment located on the main stem Illinois River in Oklahoma, along the Arkansas state line. The dam that forms Lake Frances was breached in about 1990. As a consequence, soft sediment that had been deposited in the former lake bed during the years of reservoir impoundment are now part of the flood plain and are more available for erosional processes to contribute some of this sediment (along with its P load) to the river. This would be expected to occur primarily during high flow conditions. Thus, the old Lake Frances lake bed is now a potential source of sediment, P, and other constituents to the Illinois River as it crosses the state line from Arkansas into Oklahoma (Haggard and Soerens 2006).

It is likely that the Lake Frances lakebed stored P in its sediments, especially during the years when P concentrations in the river were high (Haggard and Soerens 2006). This stored P can now be released back into the river when dissolved P in the water is less than equilibrium P concentrations with the sediment. In addition, resuspension of P-enriched sediment, due to wind (Søndergaard et al. 1992) or high stream flow can increase the concentration of P in stream or lake water.

Based on experiments using lake sediment cores from Lake Frances, Haggard and Soerens (2006) found that bottom sediments in Lake Frances have the ability to release phosphate into the river water. They measured sediment P fluxes under aerobic conditions that rivaled those measured under anaerobic conditions in many eutrophic reservoirs. They concluded:

> ***Thus, bottom sediments in Lake Frances have the potential to release high amounts of P and also to maintain P concentrations downstream at the Illinois River elevated above Oklahoma's Scenic River TP criterion (0.037 mg/L)…It is possible that remediation strategies should be considered for Lake Frances and the P- rich sediments stored within the former impoundment, if Oklahoma's Scenic River TP criterion will be achieved.***

To the best of my knowledge, Plaintiffs' consultants have not considered the influence of Lake Frances on TP concentrations in the Illinois River in any of their analyses.

Nevertheless, the potential importance of Lake Frances as a source of P to the Illinois River has been recognized for some time. The Comprehensive Basin Management Plan, prepared by the Oklahoma Conservation Commission (Haraughty 1999) stated:

> ***The collapse of the Lake Frances Dam in 1991 resulted in an additional source of nonpoint source pollution to the Illinois River basin in Oklahoma. The collapse exposed several hundred thousand cubic meters of nutrient-enriched lake bed to potential erosion.***

Haraughty (1999, page 53) went on to state, in discussing Lake Frances:

> ***It is difficult to imagine that water quality in the river can be much improved until this situation is addressed as a high potential exists for release of sediment to the river.***

The extent to which P is contributed to the Illinois River by Lake Frances was examined in a study by Parker et al. (1996). Samples of river water were collected at the Highway 59 bridge crossings above (n=130) and below (n=94; near Watts) the state line over a one year period in 1995 and 1996. Weekly samples were collected and augmented with additional storm samples. The average total P above the lake was 0.28 mg/L and below the lake it was 0.33 mg/L. Parker et al. (1996) reported that:

> ***The percent difference of 16.4% and t-test results of 0.059 for TP give borderline results as to whether a difference exists in the upstream and downstream TP concentrations.***

Thus, results of the statistical comparison were inconclusive. It is noteworthy, however, that the difference in the average results between the two stations was actually larger than the 0.037

mg/L water quality standard for TP. This suggests that if there were no sources of TP in Arkansas at all, the concentration of TP in the Illinois River in Oklahoma, just downstream from the Arkansas state line, might exceed the water quality standard solely on the basis of P contributed at the Lake Frances location, and the adjacent contributing area, between the two Highway 59 bridge crossings. Parker et al. did find a statistically significant increase (by 42%) in the concentration of total suspended solids (TSS) from the upstream to the downstream sampling location, supporting the hypothesis that the former Lake Frances lake sediment may be eroding and contributing sediments to the Illinois River.

Haggard and Soerens (2006) evaluated P release from sediments that had previously accumulated in Lake Frances. Haggard and Soerens (2006) stated:

> ***State agencies at the Arkansas-Oklahoma River Compact Commission reported conflicting trends in P concentrations and loads at the Illinois River during 2002, where P was decreasing in Arkansas and increasing in Oklahoma. One potential confounding factor in the water-quality monitoring programs between states may be that Arkansas monitors the Illinois River upstream of a small impoundment*** *(Lake Frances)* ***and Oklahoma monitors downstream from the spillway.***

Sediment equilibrium P concentrations in laboratory studies were found to range from 0.05 to 0.20 mg/L, which is greater than the total P standard applicable to this river from the Lake Frances outlet downstream through Oklahoma. Haggard and Soerens (2006) speculated that P that had been previously stored in the Lake Frances sediments during the years when P concentrations in river water were especially high, are now being released from sediment into the river water column. This would be expected to occur, in particular, when dissolved P in the river is less than sediment equilibrium concentrations, and when oxygen is depleted at the sediment/water interface or sedimentary P is introduced back into the water column by wind resuspension of bottom sediments. The latter process is known to occur in shallow, nutrient-rich lakes (Søndergaard, 1992). In discussing their findings, Haggard and Soerens (2006) concluded:

> ***This study showed the potential for bottom sediments in Lake Frances to increase P transport at the Illinois River, especially if water column dissolved P concentrations upstream from Lake Frances decrease…***

<u>Summary</u>

It is clear that there are a multitude of point and nonpoint sources of P and fecal indicator bacteria to the IRW. The Oklahoma Conservation Commission's Comprehensive Basin Management Plan for portions of the IRW that occur within Oklahoma (Haraughty, 1999) stated:

> ***However, agriculture cannot be cited as the sole source of water quality problems in the watershed... Additional nonpoint sources include recreation, the remains of Lake Frances, urban runoff, gravel mining, and streambank erosion. Combined sources*** *(sources with essentially both point and nonpoint source pollution)* ***include nurseries and urban runoff.***

The importance of these, and other (i.e., pets, row crops, hobby animal husbandry), widely distributed sources is cumulative. Some may also be important individually. For example, Haraughty (1999, page xiii) concluded that a single nursery on the shores of Lake Tenkiller contributed more than 1% of the total P load to the lake in irrigation return flows alone (irrespective of storm contributions), although controls have more recently been placed on the irrigation water at this site.

The Illinois River Management Plan (OSRC, OSU, and NPS 1999) recognized the importance of these multiple sources of NPS water pollution in the IRW. They identified a series of management goals aimed at corridor values, recreational resources, and water quality. The listed water quality management goals included:

- Minimizing alteration of stream habitat and sedimentation due to destabilization of stream banks,
- Reducing the loading of nutrients and chemicals from commercial nursery tailwater and pollutant loading into the river from urban runoff,
- Reducing nutrient inputs due to animal waste by requiring producers to complete and implement approved conservation plans,
- Protecting riparian areas from the impacts of livestock,
- Assisting in the collection of water quality data and public education.

Since the management plan was written in 1999, positive steps have been taken to address many of these goals. But it is important to note that the focus outlined for these management goals recognized that there are many contributors to NPS water pollution in the IRW, not one. Plaintiffs' consultants' claims that land application of poultry litter constitutes "the primary source" do not agree with results of previous assessments.

The importance of these various sources of constituents to streams in the IRW was almost completely overlooked by Plaintiffs' consultants. For example, Dr. Glenn Johnson (2008, page 71) reported the results of his evaluation of Dr. Olsen's PCA analyses. He stated that Dr. Olsen's SW3 and SW22 PCA runs included only 15 samples presumed or collected with the intent of characterizing sources other than poultry (2 cattle edge-of-field, 3 cattle impacted springs, 4 WWTPs, and 6 Tahlequah urban stream samples). Every one of those samples exhibited PC scores that fit Dr. Olsen's criterion for indicating what he characterizes as his unique poultry waste signature. Even if Dr. Olsen's signature does provide some interpretable information regarding contributions of various constituents to water in the IRW, it does not indicate what the source or sources of those constituents might be. Dr. Olsen largely ignored or seriously under-represented in his analyses most of the sources expected to be significant contributors in this watershed.

7. The Plaintiffs' consultants contend that P, fecal indicator bacteria, and other constituents move directly from pasture to stream, but they do not demonstrate such movement. They incorrectly claim that their edge-of-field samples demonstrate such movement.

<u>Plaintiffs' Consultants Did Not Exhibit a Clear Understanding of What Their Edge-of-Field Samples Were Intended to Represent, and Did Not Exhibit an Understanding of How to Interpret Their Edge-of-Field Data.</u>

runoff occur (Novotny 1995, p. 75). Infiltration is largely a function of permeability of soils, pre-storm soil moisture content, and vegetation cover.

Direct runoff can have several components that vary in the extent to which runoff water interacts with soil. This interaction is critical because soils tend to adsorb P and fecal indicator bacteria; water flow across the soil surface (overland flow) has less opportunity than does water flow through the soil for such interaction with soil particles. See further discussion of water flow paths in Section III.11.

Much of the surface runoff, and also much of its P load, is derived from only a small percentage of the watershed (Pionke et al. 1997, Heathwaite et al. 2000). Thus, most of the pasture area does not contribute much overland flow, and therefore does not contribute much P, to the stream. Plaintiffs' consultants did not attempt to identify these hydrologically active areas that contribute disproportionately to surface runoff or to quantify the extent to which they contribute P or any other constituent to stream water. See additional discussion of this issue in Section III.11. Furthermore, Plaintiffs' consultants did not evaluate the extent to which existing guidelines and litter application regulations in Oklahoma and Arkansas effectively reduce or eliminate poultry litter spreading in such areas.

<u>Governmental Recommendations and Regulations Regarding Land Application of Poultry Litter Consider the Importance of Transport Mechanisms</u>

It is because of the processes described above and further in Section III.11 that certain regulations and recommendations have been adopted throughout the United States and in Oklahoma and Arkansas regarding the land application of poultry litter. As described more fully in Section III.19, current regulations discourage or do not permit litter application in close proximity to a stream, on lands that routinely flood, or on frozen soils. The reason that such locations and conditions are specified as inappropriate for litter application is precisely because in such areas and under such conditions, an appreciable amount of runoff can be generated as overland flow, which is much more likely to carry P and/or fecal indicator bacteria to surface waters than are other flow paths. Most pasture areas with loamy soils (such as predominate in the IRW) contribute little Hortonian overland flow (overland flow caused by rainfall intensity exceeding soil infiltration capacity); in contrast, unvegetated soils, such as in row crop agriculture or where livestock have overgrazed and/or trampled the vegetation, generate more Hortonian overland flow. Regulations and recommendations by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), U.S. EPA, and the states of Arkansas and Oklahoma are based on an understanding of these water flow paths and transport processes. Of particular relevance is the guideline that specifies that poultry litter should not be applied within 100 feet of a stream (somewhat closer if a riparian buffer strip is installed). For example, Gburek et al. (2000a) concluded that:

> ***Field studies show that surface runoff is generated primarily from near-stream areas, typically on the order of 30 m or less from the channel for most storms. Hydrograph analysis and soil phosphorus distribution within a small intensively monitored and sampled watershed imply that surface runoff and phosphorus loss occur mainly from an area extending not much more than 60m from the channel. Also, concentrations of DP*** *[dissolved phosphorus]* ***decreased downstream and were more closely related to near-stream soil phosphorus than to the whole- watershed distribution of high phosphorus soils. In the most***

to a stream in sufficient quantity to have an appreciable effect on stream water quality. Plaintiffs' consultants fail to demonstrate that their measured concentrations of P and fecal indicator bacteria in litter, soil, or edge-of-field samples have any influence on measured concentrations of these constituents in stream waters. Plaintiffs' consultants do not provide fate and transport documentation for their assertion that constituents that might be present in poultry litter in a barn or on a field, or in ponded water at the edge of a field or in a ditch, ever actually move to a stream or to Lake Tenkiller in quantities sufficient to affect water quality in any appreciable way.

Much of the phosphate found in soil is adsorbed to soil particles or incorporated into organic matter. Because phosphate is tightly bound to soil particles, it is not easily leached out of soil and into drainage water (Pitois et al. 2001). This characteristic of P behavior is well known. Sharpley et al. (2003a, page 11) concluded that:

Generally, the concentration of P in water percolating through the soil profile is low because of P fixation by P-deficient subsoils.

Ritter (2001) concluded that:

All forms of inorganic P in soils are extremely insoluble. Because of the high adsorptive capacity of P by clays, the Fe and Al oxides leaching of P to groundwater is rare. The situation where P leaching may occur is in well-drained, deep, sandy soils.

Ritter (2001, page 151) went on to say:

Phosphorus is adsorbed by soil particles, so loss of P in surface runoff is of greater concern than leaching.

Irrigation, especially furrow irrigation, can significantly increase the P loss by both surface runoff and erosion. Furrow irrigation exposes unprotected surface soil to the erosive action of water movement (Sharpley et al. 2003a, page 12).

The propensity for both P and fecal bacteria to move from pasture to surface water is determined by a number of variables, including the loading rate of P and bacteria to the pasture, the elapsed time between loading and the occurrence of heavy rain, the intensity and duration of rainfall, the die-off rate of the bacteria in the field (which depends on such things as temperature, moisture, sunlight, and soil conditions), and the movement of water from the field into a stream. There is no *a priori* reason to expect that different species of bacteria will move in the environment in the same way, or at the same rate or that P will move at the same rate as any group of fecal indicator bacteria. The National Research Council (2004, page 173) concluded that the use of fecal bacteria indicators is based on the presumption that the indicators co-occur at a constant ratio with illness-causing pathogens. They went on to state that:

This premise is flawed … Furthermore, upon leaving the intestinal tract, microbial indicators and pathogens degrade at different rates that are mediated by factors such as the resistance to aerobic conditions, ultraviolet radiation, temperature changes, and salinity… Several studies have also found that some indicator bacteria can grow outside the human or animal intestinal system *(several cited references)****, further confounding the correlation between pathogens and indicators.***

> *flow is important as a potential vehicle for transporting P and fecal indicator bacteria to streams because runoff that follows this flow path has relatively little interaction with soil particles, which can adsorb P and fecal indicator bacteria, thereby preventing them from entering the stream. One cannot* ***assume*** *that constituents such as P and bacteria are simply washed across pastures and into streams during rain storms. For the most part, runoff does not follow such a flow path. Runoff hydrology is far more complex than that.*

Direct runoff is the water that moves from the land surface to the stream in response to a storm. It can have several components. Hortonian overland flow is surface runoff produced at the ground surface when the rainfall intensity exceeds the infiltration capacity of the soil. This type of runoff (also called "infiltration-excess runoff") can be important on clay soils that have limited infiltration capacity. Hortonian overland flow can also increase where land management practices decrease the infiltration capacity of surface soils via animal or machinery-induced compaction, overgrazing, and/or crusting of the soil surface. Another type of overland flow, called saturation-excess overland flow, occurs when the soil surface in a particular area within the watershed becomes totally saturated, and additional precipitation is unable to infiltrate into the soil. Saturation-excess overland flow often occurs in proximity to a stream, and often occurs as water comes up from deeper soil horizons or by lateral movement of soil water. Throughflow is water that infiltrates rapidly into the soil and then moves laterally.

The pathway followed by drainage water has a large influence on the extent to which various constituents will be transported from the soil surface to a stream. For example, throughflow provides proportionately more contact between drainage water and soil surfaces; overland flow provides proportionately less contact with the soil, but does provide contact with vegetation at the ground surface. The amount of contact between drainage water and soil influences the movement of many constituents, including P, in that water.

Heathwaite et al. (2000) described the hydrological pathways of P transport from agricultural fields in an attempt to account for their significance in contributing P from agricultural land to stream waters. At the hillslope scale, the principal trigger for runoff is the amount, duration and intensity of rainfall; other important factors include antecedent soil moisture, topography, and soil hydrologic conductivity. Heathwaite et al. (2000) describes saturation-excess overland flow as:

> ***Topographically-driven from spatially and temporally dynamic variable source areas (VSAs).***

It is widely believed that a large component (perhaps up to 90%) of the P load in receiving waters is derived from only a small percentage, perhaps about 10%, of the watershed (Pionke et al. 1997, Heathwaite et al. 2000).Typically, most of the pasture area does not contribute much overland flow, and therefore does not contribute much P, to the stream.

P is not very mobile in soils and tends to remain near the point of application adsorbed to soil particles (Novotny and Olem 1994, page 335). In contrast, other constituents, such as chloride for example, are highly mobile in soils and tend to move in solution along with drainage water. Clay and organic particles have a high sorptive capacity for many chemicals, including phosphates, and act as carriers for contaminant transport (Novotny and Chesters 1981, Novotny and Olem 1994, page 295). For that reason, erosion of clay particles can be an important source of P to stream waters. Erosion is commonly associated with dirt roads, roadside ditches and culverts, disturbed soils (e.g., construction sites, areas frequented by livestock, cultivated agricultural lands and row crops), and unstable stream banks. Plaintiffs' consultants did not evaluate the extent to which erosion contributes P and other constituents to streams in the IRW.

Enrichment of stream water by nutrients, fecal indicator bacteria, or other constituents is dependent on three fundamentally different factors. The first is the quantity of the constituent available in the watershed. The second is the location of the source areas that are enriched in that constituent relative to flowing stream waters. The third and final key factor is the presence of a transport mechanism. Plaintiffs' consultants generally focused only on the first of these three factors. Large quantities of P within the watershed at variable distances from the stream network can only pose a risk to water quality if there is a pathway by which to transport substantial quantities of that P from the terrestrial environment to the stream. As discussed more fully in Section III.19 of this report, current land management recommendations and regulations are aimed at all three of these key factors. Water quality protection is largely focused on identification and subsequent remediation of areas with high potential for appreciable contaminant sources, located in close proximity to a stream, with high potential for transport to the stream (Ritter and Shirmohammadi 2001, page 95).

In the IRW today, pursuant to the laws of Oklahoma and Arkansas, land application of poultry litter is constrained to fields where site-specific nutrient management plans permit land application of poultry litter and to portions of those fields that are not prone to surface transport because they do not routinely flood, are not frozen at the time of litter application, and are not located in close proximity to a stream.

Both the amount of P applied to a field and the associated soil P content provide incomplete assessment of the potential for P loss from a site because they do not account for processes that control the transport of P in surface runoff or subsurface flow (Kleinman et al. 2000, Sharpley et al. 2001). Adjacent fields can have similar soil P concentrations, yet have substantially different P loss potentials (Sharpley and Tunney 2000, Sharpley et al. 2001). Hydrological factors, including the pathway followed by water as it leaves a field, must be considered when evaluating the risk of P transfer from field applied manure to stream water (Turner and Leytem 2004, page 6106). When drainage occurs downward in the soil profile subsequent to field application of manure, P can be strongly retained in the soil. Thus, in determining the possibility of P transfer from field to stream, the water flow path is of critical importance.

Not all areas within a watershed, and not all areas within a pasture, will generate surface (overland flow) runoff, and consequently have an enhanced ability to transport NPS pollutants to streams. The areas that routinely produce surface runoff are called hydrologically active areas; the remainder of the watershed, which is not hydrologically active, contributes mainly to interflow and base flow, which are characterized by markedly increased contact of drainage water with soil particles to which P and fecal indicator bacteria can become adsorbed. Thus, interflow and base flow hydrological flowpaths favor removal of P and fecal indicator bacteria from drainage water. The areas within the watershed that tend to have the highest hydrological activity are the impervious areas (covered soils [such as for example with asphalt, concrete, or structures] with little infiltration of rain water), followed by clayey soils having low permeability, frozen soils with high moisture content, soils with high groundwater table (areas that flood and are subject to saturated overland flow), and highly compacted soils (Novotny 1995, p. 92). Impervious areas are mainly found in urban environments and other built up areas. Highly compacted soils also predominate in urban environments, including lands that are under construction or other development; they can also occur in areas with logging (compaction from heavy equipment), or areas with dense concentrations of livestock (compaction from weight of animals).

Storm runoff is typically generated primarily from a small portion of the drainage area, from the portions of the watershed that are hydrologically active. The fraction of the total precipitation volume that does not contribute to direct runoff, but rather functions to wet the soil at the beginning of the rainstorm, is stored in depressions (as depression storage), infiltrates into the soil and subsequently contributes to deep base flow, or is evaporated or transpired back to the atmosphere. These concepts are important because the pathway followed by water as it moves across the landscape and into the stream can have large impacts on the extent to which constituents such as P and fecal indicator bacteria are retained on the soil versus transported into the stream. Where drainage water interacts extensively with soil, much of the P and bacteria are removed from the water and adsorbed to the soil. Where there is little interaction of water with soil, for example during saturated overland flow or Hortonian overland flow, there is greater opportunity for these constituents to be transported from the land surface to a stream. The areas within pastures having high hydrological activity, and therefore those prone to overland flow, represent pasture conditions that are specifically targeted by current litter spreading regulations. Such litter spreading regulations were crafted with these hydrological flow paths in mind, and are intended to limit the transport of constituents such as P and fecal indicator bacteria from pasture to stream. In assuming for many of their arguments that P and fecal indicator bacteria move from pasture to field, with no consideration of the importance of transport processes and pathways, Plaintiffs' consultants fail to consider the body of scientific data and understanding that provides the underpinning for such Federal and State regulations.

It appears from page 6-4 of his report that Dr. Olsen has some understanding of the importance of flow paths to pollutant transport. He states that:

> ***if sufficient rainfall occurs in a short enough period of time, runoff is produced (i.e., not all the water can be taken up by the soil and it runs off the field).***

Dr. Olsen fails to acknowledge, however, the importance of this issue with regard to the contribution of constituents to streams from various land surfaces. Based on the rainfall, soil conditions, and topographical patterns in the watershed, it is the hydrologically active areas that generate most of the runoff. Nevertheless, neither Dr. Olsen, nor the other Plaintiffs' consultants, assessed hydrological conditions during rain events on any field in the IRW to which poultry litter had been applied.

Sharpley et al. (2001) concluded that:

> ***Generally, most P exported from agricultural watersheds comes from only a small part of the landscape during a few relatively large storms, where hydrologically active areas of a watershed contributing surface runoff to streamflow are coincident with areas of high soil P (Pionke et al. 1997, Gburek and Sharpley 1998).***

For that reason, control of P loss must focus on the critical source areas, which are dependent on transport and site management factors. Sharpley et al. (2001) went on to say that:

> ***areas contributing P to drainage waters appear to be localized to soils with high soil P saturation and hydrological connectivity to the drainage network***

> ***(Schoumans and Breeuwsma 1997). Therefore, soil P levels alone have little meaning vis a vis P loss potential unless they are used in conjunction with estimates of potential surface runoff and subsurface flow .***

Weld et al. (2001) concluded that:

> ***Threshold soil P criteria will be of limited value unless they are integrated with site potential for runoff and erosion.***

In claiming that the application of poultry litter on pasture lands in the IRW would necessarily contribute large amounts of P to streams within the watershed, the Plaintiffs are essentially ignoring both the threshold P criteria and the site potential for runoff and erosion. The threshold criteria for the IRW are specified within current litter application regulations. The Plaintiffs emphasize their claim that some soils within the IRW have P concentrations higher than the criteria, but ignore the fact that farmers are no longer allowed or expected to spread litter on those fields that have relatively high soil P. In Oklahoma, the Oklahoma NRCS Code 590 prohibits land application of poultry litter to soils that have soil test phosphorus (STP) above 300 pounds per acre, whereas Arkansas offers a sliding scale based on slope and alum treatment of litter (Clay 2008). In many of their arguments, the Plaintiffs ignore altogether the potential for runoff and/or erosion. They simply assume that P added to a pasture via land application of poultry litter will enter a stream. No analyses are performed to evaluate the likelihood that such transport of P from field to stream actually occurs in the IRW or in what quantities it might occur. No allowance is made for the fact that required nutrient management plans consider the STP value for the field as part of the basis for determining appropriate litter application rates. Some of these issues are illustrated in the photographs shown as Figure 11-1.

The main factors that control the transport of P in agricultural areas are erosion, surface runoff, subsurface flow, and distance or connectivity of the site to the stream channel (Sharpley et al. 2001). Whereas erosion is commonly very high in areas occupied by row crops, it is much less common in pasture areas. Pastures can, however, contribute substantial amounts of erosion where livestock are concentrated, mainly because livestock trampling can eliminate some or all of the ground vegetation, especially in loafing areas and other areas frequented by livestock. This is particularly problematic in streamside riparian areas that are frequented by cattle unless riparian fencing is installed. In pasture areas, erosion is more commonly derived from stream banks (especially those accessible to livestock) and from road surfaces and associated ditches. Thus, erosion in portions of the landscape dominated by pasture areas is largely an issue of animal and road management, not poultry litter management.

Some surface runoff may occur at some locations in a watershed but not actually reach a stream channel (Gburek et al. 2000b, Sharpley et al. 2001). This can be the case for areas of surface depressions on a field or for ditches associated with fields, roads, or both. Such a pattern may have occurred with ponded water or roadside ditch water sampled by Plaintiffs' consultants in their edge-of-field sampling effort. However, because Plaintiffs' consultants did not bother to track the movement of such water down-gradient from their sample collection locations, it is unknown how prevalent that pattern might be in the IRW.

Critical source areas or "hot spots" of potential P loss from soil to stream are most frequently located near the stream channel (Weld et al. 2001). This is likely the main reason why litter application regulations require a setback from stream channels when applying poultry litter on pasture land. The stream setback, plus the requirement that litter not be spread on areas that frequently flood, are intended to minimize the possibility that poultry litter might be applied to one of these "hot spots". Gburek (2000a) concluded that:

> ***A comprehensive phosphorus-management strategy must do more than simply focus on the phosphorus status of the watershed; it must also incorporate the flow system linkages. Specific control measures implemented with a phosphorus-management effort will reduce losses from a watershed most effectively if they are targeted to critical source areas (CSAs), specific identifiable areas within a watershed that contribute most phosphorus that is exported …***

According to Ritter and Shirmhammadi (2001, page 102), the most important variables that influence runoff include rainfall amount and duration, soil texture, vegetative cover, and pre-event soil moisture. Runoff is highest with intense rainfall in large amounts, on fine-textured (high clay content) soils, with little vegetative cover, and high soil moisture in advance of the storm.

Infiltration into the soil of an agricultural field is highest when the field is unharvested, intermediate if it is harvested, and much lower if fallow. For example, Novotny and Olem (1994, page 112) reported infiltration rates after one hour of about 7 cm/hr for an unharvested agricultural field, 6 cm/hr for a harvested field, and only 4.3 cm/hr for a fallow field. Novotny and Olem (1994, page 130) presented an isopluvial map of the United States showing the once-per-year, one-hour long rainfall amounts. For the location of the IRW, this amount was 3.5 cm/hr (1.4 in/hr). This is only half the infiltration rate for unharvested agricultural land reported by Novotny and Olem (1994).

For the reasons described above, not all areas within a watershed generate surface runoff and the diffuse pollution that can be associated with it (Novotny and Olem, 1994, page 142). Areas with high surface storage, such as flat cropland, and soils with high permeability, often generate surface runoff only during extreme storms (Novotny and Olem, 1994, page 143). It is generally recognized that the abatement of NPS pollution should be focused on precipitation events that are frequent, typically medium magnitude storms with rainfall amounts in the range of 0.5 to 1.5 inches, which would occur several times each year, rather than rare, large storms (Novotny and Olem, 1994, page 129). In the general area of the IRW, the storm frequency return interval for a two-year 24-hour storm is about 4.1 inches of rain; the rainfall amount for a ten-year 24-hour return interval storm event is about 6 inches of rain (USDA NRCS Technical Release 55, TR-55). Dr. Fisher testified at deposition (September, 2008, transcript page 633) for this case that a large storm in the IRW entails about 2 inches of rain.

Reduction in the amount of P loss from agricultural land to streams depends on control strategies that focus on the critical areas within the landscape. These are defined by the intersection of two major components of P movement: source and transport. As described by the USDA Agricultural Research Service (Sharpley et al. 2003a):

> ***To cause an environmental problem, there must be a source of P (that is, high soil levels, manure or fertilizer applications, etc.) and it must be transported to a sensitive location (that is, for leaching, runoff, erosion, etc.). Problems occur where these two come together. A high P source with little opportunity for transport may not constitute an environmental threat. Likewise, a situation where there is high potential for transport but no source of P to move is also of***

regulations are ineffective in that regard. Furthermore, Plaintiffs' consultants have not demonstrated that poultry litter application is responsible for observed concentrations of these constituents in non-urban streams. Rather, they ignore the likely importance of cattle, erosion, septic systems, other livestock, wildlife, and other well known potential sources of these constituents in non-urban areas.

Plaintiffs' consultants did not demonstrate that land application of poultry litter plays an important role in contributing P or fecal indicator bacteria to streams in the IRW. Furthermore, to the best of my knowledge Plaintiffs' consultants did not present a clear indication that land application of poultry litter causes or contributes to high concentrations of P or fecal indicator bacteria in streams **anywhere** under the same general environmental conditions and the same guidelines and regulations as are now applicable in the IRW**.**

Most of the published literature that documents movement of P from pasture land subsequent to poultry litter land application was either based on experimental studies that involved small plots or treatment boxes, and/or relied on irrigation with artificial rainfall at rates that exceed typically observed rainfall intensities recorded in the IRW (Table 11-1**)**. Some studies have been conducted on clay soils (which promote overland flow) or may have included the potential influences of both livestock grazing and land application of poultry litter, with no ability to discriminate between these two potential sources.

12. Plaintiffs' consultants have not identified a unique signature that indicates the presence of water contamination from poultry litter application, or any other potential source of P or fecal indicator bacteria to stream water in the IRW. Plaintiffs' consultant, Dr. Olsen, incorrectly claimed on page 2 of his May 14, 2008 report for this case that his PCA analyses:

> ***identified two major sources of contamination in the IRW: poultry waste disposal and WWTP discharges.***

He went on to state:

> ***Poultry waste is by far the dominant contamination source in the IRW when compared to other sources….chemical contamination from cattle waste is not dominant in the basin and only represents a minor source. In the PCA, the chemical and bacterial composition of poultry waste creates a distinct chemical signature that contains both phosphorus and bacteria.***

There are numerous problems associated with Dr. Olsen's interpretation of his PCA analyses. These problems are discussed at length in several of the expert reports prepared for the Defendants in this case. Some of the most important, in my view, are the following:

1) Dr. Olsen did not collect and analyze samples to reflect the presence of the many known and suspected sources of NPS pollution of stream water that are found in the IRW, including septic systems, runoff from roads and other erosion sources, urban storm runoff, swine manure, biosolids, and commercial fertilizer application. He collected only a few samples for his PCA to characterize the composition of runoff from cattle pasture areas. If Dr. Olsen's PCA was intended to indicate contaminant sources, as he claims, at a minimum he should have adequately sampled all of the

potential sources expected to be important. Rather, Dr. Olsen's sampling of potential source areas was focused almost entirely on his edge-of-field samples, which he **presumed** were affected by poultry litter, and (in most cases) only poultry litter. As reported by Dr. Glenn Johnson (November, 2008), Dr. Olsen collected samples to characterize the signature of potential sources for his SW3 PCA run (his primary run that was focused on surface waters). But 64 of those were edge-of-field samples, and only 6 were collected with the intent of examining the signature of other sources: 4 to characterize WWTP effluent and 2 to characterize cattle pastures to which poultry litter had never been applied. It appears that Dr. Olsen **assumed** that land application of poultry litter was the only important source of NPS water pollution in the IRW, and that it was therefore not necessary to sample other sources with any degree of rigor, or (in most cases) at all. Since Dr. Olsen assumed prior to conducting his analysis that poultry litter was the dominant source, it is not surprising that he would conclude as a result of his analyses that poultry litter was the dominant source.

2) Interpretation of his principal components as indicative of source types is unfounded. Dr. Olsen interprets his principal component 1 as indicative of influence by poultry litter on water quality. This is a subjective judgment. His PC1 axis could represent anything, or it could represent nothing. In order to accept that PC1 reflects poultry influence, we must accept Dr. Olsen's judgment on that. The PCA method does not tell us what PC1 represents; Dr. Olsen tells us what he believes it to represent. Dr. Olsen does not offer sufficient documentation to demonstrate that his interpretation is correct. Furthermore, Dr. Olsen assumes that his PC1 and PC2 axes can discriminate among sources. In fact, these derived factors can reflect many different things; they could reflect different sources, or differences in contaminant behavior in the environment, or (as discussed by Dr. Glenn Johnson's rebuttal report; Johnson 2008) the propensity for individual constituents to travel through the watershed in dissolved versus particulate forms, some combination of the above, or some other factor(s) that reflect differences and similarities among data points. The PCA really only indicates the extent of similarity among data points. It does not tell the user how or why the data points are more or less similar or different. That must be decided by the user, and that decision is subjective. Dr. Olsen provides no scientifically defensible evidence that his PC1 and PC2 axes reflect sources, poultry litter or otherwise. He defends his interpretation on the basis of spatial analysis of samples from only a few locations. This is described by Dr. Glenn Johnson (2008), who conducted a much more extensive examination of the spatial patterns in Dr. Olsen's PC scores. Dr. Glenn Johnson (2008) reported a large number of inconsistencies in Dr. Olsen's interpretation. In fact, many sample points that showed PC1 scores greater than his 1.3 cutoff (supposedly reflecting poultry dominated water quality) were located in areas of low poultry house density (Johnson's Figure 2-5). Many sample points that showed PC1 scores that were greater than 1.3 were located in areas that were immediately downstream from urban development (Johnson's Figure 3-1). Thus, the spatial patterns in Dr. Olsen's data do not support his contention that his principal components reflect different pollutant source types. It is clear that PC1 does not represent poultry influence (Glenn Johnson 2008). It is therefore unclear what value his PCA provides to the Plaintiffs' case.

3) Dr. Olsen claims that the ratios and concentrations of various constituents in various portions of the watershed reveal where those constituents came from. This ignores the likelihood that different chemical and biological components move through the environment to varying degrees and are diluted to varying degrees (Connolly 2009). He simply **assumes** that similarities in the chemical and biological constituents in presumed source types or source areas are conserved as those constituents move down through the watershed from poultry barns to fields, to soil, to streams, to Lake Tenkiller. Yet Dr. Olsen provides no evidence to support that assumption.

4) The scores plot for Dr. Olsen's primary PCA run (termed SW3), presented as Figure 6.11-18a by Dr. Olsen and again as Figure 2-1 by Dr. Glenn Johnson, clearly shows that Dr. Olsen did not obtain good clustering of data points along his PC1 and PC2 axes, which are the only axes that he judged to be important to his allegations. His selection of PC1 equal to 1.3 as the benchmark for identifying samples impacted by poultry litter is completely arbitrary, and he does not adequately defend this arbitrary selection that is so central to his PCA interpretation. Dr. Olsen makes the subjective determination that his quantification of PC1 in a water sample higher than 1.3 indicates that poultry litter is the dominant influence on the chemistry and biology of that water sample. He offers absolutely no basis for that judgment. Incredibly, his plot of PC1 versus PC2, on which he makes that judgment, illustrates that he draws his subjective line (at PC1 equal to 1.3), right in the middle of the densest concentration of data points on his graph (his Figure 6.11-18e). His PC1 versus PC2 plot does not reveal any objective basis for determining at what PC1 score he should set his arbitrary boundary between poultry dominant influence and not poultry dominant influence. Again, we are asked to accept Dr. Olsen's interpretation of where that arbitrary boundary should lie.

5) Even Dr. Olsen recognized the subjective nature of his benchmark of PC1=1.3 as a determinant of poultry impacted surface water. He arbitrarily changed his interpretation of six stream samples collected near Tahlequah from "poultry impacted" to "not poultry impacted", even though his PC1 score was greater than 1.3 for each of those samples; Dr. Olsen did not reveal in his report that he had changed these data points. He stated in his deposition that he made this change because:

> ***I decided that those were not impacted by poultry, and I colored them green…***

This subjective change in interpretation by Dr. Olsen is discussed in detail by Dr. Glenn Johnson (2008, See Dr. Johnson's Figures 3-1 and 3-2). There is no place in objective science for Dr. Olsen's decision to arbitrarily change the color (source interpretation) of those six sample locations, especially without acknowledging that subjective action in his report. Dr. Olsen also collected three samples of WWTP effluent from the treatment plants in Springdale, Rogers, and Siloam Springs, along with one sample of stream water just downstream from the Lincoln WWTP. Dr Johnson (2008, page 37) indicated that all of those samples had PC1 scores in Dr. Olsen's SW3 PCA run that were greater than 1.3, and Dr. Olsen therefore classified them as poultry impacted. In deposition, Dr. Olsen acknowledged that these samples should not have been classified as poultry impacted, even though they had PC1 higher than his arbitrary 1.3 cutoff value, and that they needed to be removed from his poultry-impacted calculations. Thus, Dr. Olsen apparently feels that he should have arbitrarily changed the color of those dots on his map as well. The PC1=1.3 criterion only seems to apply as a benchmark for indicating that water is poultry impacted in situations where Dr. Olsen agrees that the sample might be poultry impacted. This is not a unique signature of impact of a particular source; it is a subjective determination made by one person (Dr. Olsen) as to what is the cause of impact.

6) A high percentage of the samples used by Dr. Olsen in his PCA had missing values, especially for fecal indicator bacteria (among the most important parameters in this case). For the missing values, Dr. Olsen substituted the mean of all of his samples, regardless of whether they came from edge-of-field or stream, regardless of whether that stream was located in a forest or a pasture or below a WWTP. This would result in the potential for serious bias in the samples that had substituted data. Dr. Olsen did not investigate or attempt to correct for such bias. Furthermore, Dr. Cowan (2008,) concluded that :

> ***Dr. Olsen has plugged in so many missing values that a very significant part of the dataset is made up by Dr. Olsen.***

Dr. Cowan (2008, his Chart 6) also showed that observations that were missing some data were unlike those that were not missing data, suggesting that Dr Olsen's made-up data may have biased these sample points.

These, and many other, problems associated with the conceptualization, implementation, and interpretation of Dr. Olsen's PCA are discussed in greater detail in the rebuttal reports of Dr. Glenn Johnson (2008), Dr. Steven Larson (2008), and Dr. Charles Cowan (2008). Taken together, these problems indicate that Dr. Olsen's conclusion that his PCA identifies the principal sources of P and fecal indicator bacteria in the IRW is without merit.

13. There are many known sources of NPS pollutants in the IRW. Plaintiffs' consultants provide no convincing evidence that poultry litter application is significant, compared to other known sources.

In Sections III.5 and III.6 of this report, I discuss some of the major sources of P and fecal indicator bacteria to streams in urban and agricultural areas, respectively. The most important in the IRW are probably WWTP effluent, urban runoff, cattle, septic systems, erosion, Lake Frances, other livestock, and wildlife. Because many of these potential sources of point and nonpoint source contribution to streams are at least partly restricted to urban and/or agricultural land use, nutrient (P and N) concentrations in some areas in the United States have been shown to increase with percent agriculture and decrease with percent forest (Riseng et al. 2004). This is a well known pattern. It is to be expected that concentrations of P and fecal indicator bacteria within the IRW would be higher in areas influenced by urbanization, agriculture, and other human activities, as compared with forested areas. One cannot determine, based solely on that pattern, the relative importance of the different potential sources of these constituents within the urban and agricultural land use types. Plaintiffs' consultants did not conduct additional analyses to try to determine the relative importance of these various potential pollution source types. Rather, they generally ignored or dismissed them as unimportant.

through 2002. Haggard and Soerens (2006, page 281), citing the Ekka et al. (2006) study of the effects of municipal effluents on streams in the IRW, also acknowledged that P concentrations in the IRW have been decreasing over time; they credited reductions in municipal discharges for at least part of the decrease in stream P concentration.

Plaintiffs' consultants collected lake water data from Lake Tenkiller that allow an evaluation of the extent to which water quality has changed over time, although there may not be enough years of data to conclude that there have been statistically significant changes in recent years. The concentrations of total P at the lacustrine (lake-like) sampling stations, LK-01 and LK-02 in Lake Tenkiller appear to have decreased in recent years, based on data summarized by Cooke and Welch (2008, their Figure 7). I have extracted the data from Cooke and Welch's Figure 7 for the lacustrine lake sampling site closest to the dam (site LK-01) and show their measured total P values at that site (six years of data represented). Total P concentrations in the more recent years (2005-2007) were about half the values measured in the earlier years (1974, 1992, 1993; Figure 15-3). I also show in Figure 15-3 the median and quartile values of total P measured at sampling sites near the dam in each of 135 reservoirs in Missouri, reported by Jones et al. (2004). The comparable total P values measured in Lake Tenkiller during the three most recent sampling years (Cooke and Welch 2008) are lower by about a factor of two than the 25th percentile of the distribution of the Missouri reservoir data. In other words, more than 75% of the Missouri reservoirs studied by Jones et al. (2004) had total P concentrations that were much higher than Lake Tenkiller.

The more recent years for which total P data were reported for Lake Tenkiller site LK-01 by Cooke and Welch (2008) were drier than the earlier years for which they reported data, as represented by total stream discharge at the two principal downstream USGS gaging stations on the Illinois River and Baron Fork (Figure 15-4). This could cause lower concentrations of total P in lakewater because more P is generally transported to the lake under high flow conditions, which are more common during wet years, as compared with lower flow conditions, which are more common during drier years. Clearly, 1974 was a wet year, and river discharge was high. The years 1992 and 1993 were also characterized by higher river flows than the long-term median values, whereas 2006 was a drought year (both on an annual and a summer basis); 2005 was dry during summer but near the median value on an annual basis. The year 2007 was fairly typical of the long-term record. However, there were large differences in river discharge within the three most recent years sampled and reported by Cooke and Welch (2008) on both an annual and a summer basis. Total summer flow in 2007 was more than double that of either 2005 or 2006; total annual flow in 2005 was more than three times higher than in 2006, and total annual flow in 2007 was more than twice as high as 2006. Despite these large differences in flow within those three years, the concentrations of total P in the lacustrine portions of Lake Tenkiller reported by Cooke and Welch were remarkably similar in 2005, 2006, and 2007. In addition, the differences in annual flow between 2005 and 2006 were more than twice as large as the differences between 2005 and 1992. A similar pattern is seen for summer values: the difference in flow between 2007 and 2006 is larger than the difference between 1993 and 2007. It is therefore unlikely that the large decrease in total P observed between the sample occasions in the early 1990s compared with 15 years later can be attributed to differences in river flow. If that was the case, we should also see large differences in total P concentration within the more recent three year period (2005-2007); we do not. Thus, it is unlikely that the observed decrease in total P between the 1990s and the period 2005-2007 is attributable to the drier conditions observed during the more recent years of data collection.

have been many contributors to P loads to Lake Tenkiller. His misguided effort to pin the responsibility on one source (land application of poultry litter) is without merit.

17. *Importing of P into the IRW in poultry feed does not demonstrate that the P imported into the watershed contributes P to streams. The P mass balance described by Meagan Smith and Dr. Engel reveals little about the relative importance of the various sources of P contribution to streams in the IRW. Importation of P into the watershed is only one component of the complicated set of processes that influence the potential transfer of P from pasture to stream.*

Meagan Smith performed mass balance calculations of P inputs and outputs to the IRW. Other Defendants' experts address errors or shortcomings in how this mass balance was calculated (c.f., Clay, 2008). Dr. Clay (2008) estimates that cattle produce more than twice as much wet manure in the IRW as do poultry. In addition, Dr. Clay estimates that cattle manure produced in the IRW contains more P than poultry manure produced in the IRW, and much of that material is deposited by cattle directly into streams or adjacent to streams where it can be easily transported to streams during rain storms. I therefore do not assume that Ms. Smith's calculations are correct or representative. Nevertheless, it is important to point out that this mass balance, even if it was done correctly, provides very little information about the likelihood of P transfer to stream water from poultry litter or any other source of P in the IRW. In the Executive Summary of her May 2008 report, Ms Smith indicates that:

> ***The purpose of the [**mass balance***] study was to determine the source(s) of phosphorus causing eutrophication of Tenkiller Ferry Reservoir and water quality degradation of the Illinois River and its tributaries.***

Despite her goals, a mass balance such as was performed by Ms. Smith for this case **cannot** identify P sources to stream or lake water. Nevertheless, many of the Plaintiffs' consultants cite this mass balance as one of the principal pieces of evidence in support of their contention that concentrations of P in stream water in the IRW can be attributed to land application of poultry litter. See, for example, Dr. Fisher's deposition testimony (September 4, 2008, pages 342 and 348).

There are three major problems with the ways in which Plaintiffs' consultants interpret the results of Ms. Smith's calculations. Each is described below.

First, and most importantly, Plaintiffs' consultants failed to acknowledge that the mere presence of P in the watershed does not demonstrate movement of P into streams. In order for P placed on the land to cause or contribute to P in a stream, in addition to being present within the watershed, the P must be placed in sufficient proximity to a stream and in addition there must be a transport mechanism to move that P from the land to the stream. Plaintiffs' consultants make no allowance for the importance of proximity to streams and/or pollutant transport mechanisms within the watershed. Based on the logic of Plaintiffs' consultants, I could import a million tons of P into the IRW and place it in a warehouse. On this basis, because I would represent the largest importer of P into the watershed, Plaintiffs' consultants would conclude that I was not only the largest importer of P from outside to inside of the watershed, but also that I was the major source of any P found in stream water throughout the watershed. Obviously, the P stored in my warehouse would not be contributing to adverse effects on stream water quality. The reasoning offered by Plaintiffs' consultants is faulty because it does not address issues of proximity of P-containing poultry litter to streams or the availability of transport mechanisms from the site of litter application to stream water. There is an entire field of science that attempts to address these complex issues. It is totally insufficient to merely quantify which potential sources bring the most P into the watershed; this quantification (even if it is done correctly) reveals little about the relative importance of the various potential sources of P to streams.

The second major problem with the way in which Plaintiffs' consultants use the results of this mass balance is that they dismiss the importance of cattle as contributors of P to streams on the basis of Ms. Smith's assumption that, because they graze on pasture grass with relatively little supplemental feeding, cattle:

> **"recycle the phosphorus already in the landscape."** (Smith 2008, page 3)

On this basis, Ms. Smith essentially ignores any possibility that cattle act as a source of P to streams. This is not consistent with the well-known fact that in many watersheds, including many in Oklahoma for which Total Maximum Daily Loads (TMDLs) have been calculated, cattle have been judged to represent the largest source of fecal indicator bacteria to streams. If cattle are the most important contributors of fecal indicator bacteria, it is likely that they may also be important contributors of P as well. Thus, it is not appropriate to simply dismiss their potential importance. A bacterial TMDL analysis for the ODEQ for the Upper Red River (Parsons 2008b, page 3-12) concluded that:

> ***Cattle appear to represent the largest source of fecal bacteria***

in this watershed. The same conclusion was drawn in bacterial TMDL analyses for ODEQ for the following additional watersheds:

- Boggy Creek area (Parsons 2007b, page 3-6)
- Sans Bois Creek area (Parsons 2008a, page 3-9)
- Little River area (Parsons 2007d, page 3-6)
- Washita River (Parsons 2007a, page 3-13)
- Canadian River (Parsons 2006b, page 3-8)
- Arkansas River sections and Haikey Creek segment (Indian Nations Council of Governments 2008, page 3-15)
- Neosho River (Parsons 2008c, page 3-14)
- Lower Red River (Parsons 2007c, page 3-10)
- Upper Red River (Parsons 2008b, page 3-12)

It seems odd that in all these TMDL analyses that have recently been conducted for ODEQ, it was concluded that cattle appear to be the most important source of fecal indicator bacteria in each watershed, yet Plaintiffs' consultants conclude that the 200,000 cattle in the IRW are unimportant in regard to transport of P to streams. The cattle feces that contribute fecal indicator bacteria are the same feces that contribute P to streams and to riparian areas adjacent to streams. In addition, cattle contribute to stream bank and riparian zone erosion, thereby further increasing their contribution of P to streams. It seems especially odd that Plaintiffs' consultants dismiss the importance of cattle with the weak argument that cattle merely recycle nutrients that are already present on the land surface.

Consider also that the Comprehensive Basin Management Plan for the Oklahoma portion of the IRW (Haraughty 1999, page vii) estimated that cattle (dairy plus beef) excrete more P within the watershed than do poultry (chickens plus turkeys). Dr. Clay (2008) reached the same conclusion. Haraughty (1999)) went on to state:

> ***This is important because beef cattle management is such that cattle often have direct access to streams. Thus, cattle may act as a point source and deposit the nutrients directly into the stream, while poultry waste accesses the stream mainly through overland flow. In addition, pasture management is not always optimal. Grazing land is scarce and pastures are often over grazed, resulting in poorer pasture with a lower capacity to process animal waste and prevent it from reaching the stream.***

Dr. Fisher acknowledged in his September 4, 2008 deposition (page 450-451) that Plaintiffs did not evaluate the extent to which cattle convert vegetative P into a soluble form present in cattle feces and transport it from the pasture to the water course or adjacent to the water course.

Third, Plaintiffs' consultants do not acknowledge the presence (based on Dr. Engel's GLEAMS model, as summarized by Dr. Bierman) within watershed soils of P in amounts that far exceed the quantities imported into the watershed in poultry feed. Dr. Bierman concluded that Plaintiffs' consultants' estimate of P transfer into the IRW for poultry (4,642 tons of P per year) represents less than 0.07% of the P present in soils within the watershed, as represented in Dr. Engel's GLEAMS modeling effort (Bierman 2009). Thus, if one assumes that Plaintiffs' consultants' estimate of P import into the watershed for the poultry industry is correct and that Dr. Engel's GLEAMS model estimate of the size of the soil P pool within the watershed is correct, P application to soils in the IRW each year through land application of poultry litter would change the amount of P in the watershed soils by less than one tenth of one percent, even if all of this P remained in the soil, with no export via runoff or animal harvesting.

As described above, Plaintiffs' mass balance, which is cited by several of Plaintiffs' consultants (including Dr. Engel) as an important part of their weight of evidence evaluation, only focuses on P sources; it totally ignores transport. EPA recognized the fallacy of this approach. In the text of their revised CAFO guidelines in 2003 (Page 7227), EPA stated with respect to manure or poultry litter land application:

> ***However, it is also possible that an operation might land apply in excess of agronomic rates but still not discharge, depending on such factors as annual rainfall, local topography, and distance to the nearest stream. The Panel recommended that EPA consider such factors as it develops requirements related to land application.***

Thus, EPA recognized that a P source, on its own, is not sufficient to cause increased concentrations of P in stream water. Availability of transport mechanisms must also be considered.

Plaintiffs' consultants used their mass balance calculations as the basis of their claims that:

> ***Poultry production within the Illinois River Watershed is currently responsible for more than 76% of P movement into the watershed (Engel, May 2008 Report, page 32)***

Other consultants for the Plaintiffs also drew conclusions or made assumptions on the basis of these mass balance calculations. For example, Dr. Stevenson stated in his January 8, 2009 deposition (transcript page 179) stated, when asked about sources of P in the IRW:

> ***Well, based on the information I have about the amount of phosphorus that comes in and the phosphorus concentrations that were in the stream, my reasonable conclusion is that poultry houses and the spreading of the manure on the lands around the streams is the source of that phosphorus in the stream.***

Such claims are misleading. Plaintiffs' mass balance tells us little about the extent to which land application of poultry litter may or may not add P to streams in the IRW. It certainly does not provide the basis for such a quantitative estimate. The extent to which any one industry is responsible for movement of P, or any constituent, into the watershed on its own is not an important determinant of the causes of water pollution of streams within that watershed.

18. Plaintiffs' consultants' water quality sampling program lacked appropriate quality assurance.

A number of breaches of standard sampling procedures by the Plaintiffs' field sampling personnel were recorded by Conestoga-Rovers and Associates (CRA), who observed, photographed, and shot video footage of some of the state's sampling effort in 2006 and 2007. In my opinion, these procedural breaches that were summarized by CRA were sufficiently serious as to cast doubt on the ability of Plaintiffs' consultants to defend the validity of their field data. Some of the analyses conducted by Plaintiffs' consultants for this case relied on only a small number of data points to form the basis for their conclusions. This was particularly the case for some of Dr. Olsen's analyses of potential sources of constituents to stream water in his PCA work and regression analyses of Dr. Engel's sub-basins that he evaluated for the relationships between poultry house density and other variables. In such cases, if even a relatively small number of samples were compromised by poor quality assurance procedures, those errors could affect the results of analyses and validity of conclusions drawn from those analyses.

I am especially troubled by the report provided by CRA indicating that the sampling crews collected water samples from 1) springs that were not sampled at the location where they emerged to the ground surface, 2) spring sampling locations that were accessible to cattle, and 3) springs in which the sampling person stood (subsequent to walking across pasture land) in the water, thereby disturbing the sediment upstream from the sampling location, prior to collecting the water sample. Each of these issues has the potential to introduce substantial bias into the resulting data, thereby rendering the data indefensible, as explained below.

In his summary of the Plaintiffs' field sampling program for this case (Brown 2008, page 1-11), Plaintiffs' consultant Darren Brown defined a spring as:

land application of poultry litter in the IRW is subject to the rules and regulations of Oklahoma and Arkansas (September 4, 2008 deposition testimony, page 473). He also acknowledged that, even though Plaintiffs' consultants had employed a team of observers to drive through the IRW and examine poultry operations, he was not aware of any circumstances where poultry litter has been applied in the IRW in violation of the provisions of that landowner's nutrient management plan or animal waste management plan.

Nutrient management plans are prepared to govern land application of poultry litter. They include provisions that are intended to minimize conditions that favor transport of P or fecal indicator bacteria to streams and/or to ground water.

Existing regulations and guidelines include avoidance of land application of poultry litter in pasture areas and under conditions that would be expected to increase the likelihood of either surface water or ground water contamination with some of the constituents in poultry litter, especially P and fecal indicator bacteria. The following conditions are avoided:

- Fields having high P content in the soil
- Areas that frequently flood
- Areas near a stream
- Frozen or water-saturated soil
- Shallow or rocky soil
- Steep slopes.

In addition, plans for nutrient management are developed under specific technical guidelines. Soil sampling and laboratory analysis is conducted in accordance with land grant university guidance or industry practice.

Within the pasture/hay land use areas in the IRW, soils are generally loamy. Less than 1.6 percent of these soils are classified in the USDA NRCS Soil Survey Geographic Database (SSURGO), as "clay" soils, the general class of soil particle size distribution which would be expected to promote overland flow. In addition, less than 4% of these pasture/hay soils are expected to be less than 10 inches deep, according to the average depth as reported by SSURGO. This is the depth identified by the Oklahoma NRCS Code 590 as too shallow for land application of poultry litter.

The Arkansas NRCS Code 590 (December 2004) specifies that manure shall be applied at rates to meet crop P needs when the P Index rating is High, and there shall be no manure application on sites with P Index rating of Very High. Manure application is not to occur on sites considered vulnerable to off-site P transport unless appropriate conservation practices, best management practices or management activities are used to reduce the vulnerability to P runoff. In areas with identified nutrient-related water quality impairment, an assessment shall be completed of the potential for P transport using the P Index. The results of this assessment shall be included in the nutrient management plan. Nutrient applications shall consider minimum application setback distances from environmentally sensitive areas.

Chapter 9 of the Arkansas Nutrient Management Planners' Guide (Daniels et al. Undated) provides an overview of nutrient planning in Arkansas. This document describes several sets of regulations that require livestock operations to implement plans. These include: 1) Arkansas

They cautioned that when models are used in a regulatory capacity, because of the potential for model results to cause direct economic harm on individual producers, these:

> ***models should undergo additional validation and subsequent refinements prior to regulatory application.***

Plaintiffs' consultants did not conduct such validation exercises. In fact, measured values of P concentration in edge-of-field samples and stream samples at the hundreds of locations that Plaintiffs' consultants sampled in their field efforts for this case were never used to constrain or evaluate Dr. Engel's watershed modeling. Results of Dr. Engel's routing model application were only compared with stream water quality data collected at the bottom of the watershed, near Lake Tenkiller. See further discussion of this issue in the expert report prepared by Defendants' expert, Dr. Bierman. Dr. Engel applied a flawed approach when developing his model (Bierman 2009). Therefore, it would be possible for Dr. Engel to obtain a good fit between his modeled values and the measured values of TP at these downstream locations irrespective of whether his GLEAMS model estimates that he developed for the upper reaches of the watershed were correct, or were representative of the various potential sources of P across the landscape that Dr. Engel attempted to model.

22. *Plaintiffs' consultants provide no convincing evidence to indicate that land application of poultry litter is an important source of P and fecal indicator bacteria to streams in the IRW. To the best of my knowledge, Plaintiffs' consultants do not provide a single example of transport of P to stream water from land application of poultry litter in a comparable field setting and set of litter application guidelines under normal rainfall regimes, either within the IRW or anywhere else. Examples of small plot experimental treatments that involved artificial rainfall at intensities that seldom occur in the IRW (for example, Edwards et al. (1995), Daniel et al. (1995) are not representative of typical field conditions and therefore are of minimal relevance to water quality issues within the IRW. Such studies merely illustrate that, if it rains with a sufficient intensity (typically greater than or equal to 5 cm/hr [about 2 inches per hour]), it is possible to generate overland flow on some soils and therefore contribute P from soil to down-slope stream waters at those specific locations. Such studies have been valuable scientifically to improve understanding of P dynamics in simulated field settings, but they cannot be used to justify Plaintiffs' consultants' claims that under normal rainfall regimes in the IRW, an appreciable amount of P is transported in overland flow from litter-amended pastures to streams. First of all, it is quite possible that some overland flow might occur in certain areas, and subsequently that water may infiltrate into the soil lower on the hillslope, removing dissolved P from the water before the water reaches a stream. But most importantly, it simply does not rain in the IRW with such a high intensity on any except the rarest of occasions.*

Many of the datasets used for development of models and study of P transport mechanisms have been produced under artificial simulated rainfall (Edwards et al. 1995, Sauer et al. 2000, Kleinman et al. 2002, Radcliffe and Nelson 2005). However, the predictive relationships developed from simulated rainfall are not necessarily transferable to natural conditions. Radcliffe and Nelson (2005) concluded:

Because of the differences between P losses observed under simulated rainfall vs. natural rainfall, models should be validated with datasets derived from natural rainfall studies.

Published experimental studies that relied on simulated artificial rainfall to determine movement of P from fields amended with poultry litter typically applied artificial rain at intensity equal to 5 cm/hr or higher. Based on data from the National Climatic Data Center (Table 11-1), it seldom rains in the IRW with such intensity. Thus, results of these experimental studies are not directly applicable to questions regarding the extent to which P may move off pastures to which poultry litter had been land applied and into streams in the IRW.

I examined hourly precipitation data available for the IRW over the period from 1949 to 1997 for Tenkiller dam (at the bottom of the watershed) and from 1966 to 2008 for Fayetteville, Arkansas (at the top of the watershed). During only 0.05 % to 0.07% of the hours for which rainfall was recorded at these two monitoring stations (six individual hours at each station over a period of record of more than 40 years at each site) was the hourly rainfall intensity higher than 5 cm per hour (1.97 inches per hour). Only 0.1 percent of the hours for which rainfall was recorded exhibited hourly rain intensity higher than 1.7 inches per hour. On average, only during one hour out of every seven or eight years was the measured precipitation greater than 1.97 inches (2 cm). Thus, the publications cited by Plaintiffs' consultants, in support of their contention that P runs off pasture lands subsequent to land application of poultry litter, are not directly relevant to Plaintiffs' consultants' claims to the extent that these publications employed artificial experimental rain application at rates higher than commonly occur in the IRW.

Plaintiffs' consultants contend that one factor (land application of poultry litter) is the predominant cause of water quality impairment in the IRW. Plaintiffs' consultants offer no scientifically defensible evidence in support of that contention. Due to the large numbers of people and livestock (especially cattle) in the IRW, and as is indicated in the available data for the watershed and the body of scientific information on watershed sources of stream water pollution in general, it is clear that there are multiple sources of point and nonpoint contributions of P and fecal indicator bacteria to surface waters in the IRW. Plaintiffs' consultants offer no scientifically defensible evidence that land application of poultry litter is important in that regard. They certainly provide no scientifically defensible evidence that land application of poultry litter constitutes the dominant source. In contrast, stream water quality data collected by Plaintiffs' consultants for this case illustrate that P concentrations in stream waters in the IRW largely originate in and around urban areas and WWTP facilities.

With regard to potential bacterial contamination of water in the IRW, Defendants' expert Dr. Herbert DuPont concluded (2008, page 19) that Plaintiffs focused only on poultry as the potential source of environmental contamination, and that they made a non-scientific decision to pursue the poultry industry ignoring all other sources of contamination. Cattle are known to harbor and excrete into the environment bacterial pathogens that can cause human disease, including strains of pathogenic *E. coli*, *Cryptosporidium*, and *Salmonella*. Wildlife regularly add fecal indicator bacteria to stream water (Myoda 2008). Dr. DuPont reviewed studies indicating that the three most important sources of bacterial contamination of water in the United States are people, cattle, and wildlife. Plaintiffs' consultants ignored these, and assumed that human pathogens were present in the IRW even though they generally did not find them, and further that these pathogens that they did not find were contributed by poultry.

The primary approaches offered by Plaintiffs' consultants in their efforts to assign responsibility to the poultry industry for P that occurs in streams in the IRW are: 1) the edge-of-field water quality data, 2) Dr. Olsen's PCA analysis and 3) results of GLEAMS modeling by Dr. Engel. The edge-of-field data reveal nothing about specific sources of P beyond what Plaintiffs' consultants **assume**; similarly, edge-of-field data do not indicate that any of that water sampled at the edge-of-field (and at the edge of roads and along ditches) actually moved to any stream. As described more fully in other sections of this report, Dr. Olsen's PCA was not able to discriminate among the potential sources of P to stream waters in the non-urban portions of the watershed. The GLEAMS modeling relied on a totally empirical routing model to estimate the contribution of various potential sources to the upper end of Lake Tenkiller. As shown by Dr. Bierman (2008), varying model inputs can yield acceptable model estimates of P concentrations in stream water at the inlet to Lake Tenkiller. The model calibration demonstrated by Dr. Engel does not confirm that the parameters that he used in his model to apportion P sources are correct or even reasonable.

Radcliffe and Nelson (2005), in their position paper for SERA-17, summarized the group's position on watershed-scale modeling of P loading as follows:

> ***In our opinion, watershed-scale predictions of loadings to lakes are not reliable unless extensive, site-specific calibration is used. The same can be said for short-term (daily) predictions at the edge-of-field scale. These types of predictions remain in the research development stage. The capability to make predictions at this scale is, however, an appropriate long-term goal.***

As discussed by Dr. Bierman, in his expert report for this case (January, 2009), Plaintiffs' consultants did not provide site-specific calibration for their modeling effort anywhere except at the bottom of the watershed. As a result, they cannot scientifically defend the conclusions they draw from their model results with respect to sources of P within the watershed. Neither plaintiffs' edge-of-field data nor their stream data from sites scattered throughout the watershed were used to constrain their GLEAMS model calibration. Radcliffe and Nelson (2005, page 4) went on to say, in discussing the use of field-scale P loss model predictions to regulate individual farmers or producers, :

> ***caution must be used when models are applied for these expanded purposes. For example, because of the potential for model results to inflict direct economic harm on individual producers, models should undergo additional validation and subsequent refinements prior to regulatory application.***

The models applied by Plaintiffs' consultants in this case did not undergo such validation and refinement.

Dr. Harwood claims that she can identify the origin of fecal indicator bacteria that she finds in Lake Tenkiller (or elsewhere in the IRW) on the basis of the number of small pieces of bacterial DNA that she finds in the water. Her analyses **assume** that other bacteria (such as for example a fecal indicator like *E. coli* or potential pathogens like *Salmonella* or *Campylobacter*) will move along the same pathways (from source location through and over soils, through ground surface vegetation, and through stream systems, past potential predators and life-threatening conditions (sunlight, heat, drying, etc.) and finally arrive at her sample location) at the same rate and in the same proportion as her presumed *Brevibacterium avium*. There are many problems associated with having to make such assumptions. First, bacteria are different shapes and will therefore move through soil spaces at different rates. Second, bacteria are extremely small and the size of a single piece of bacterial DNA is much smaller than the entire bacterium from which it is extracted. For example, the length of *E. coli* is one-fortieth the width of the average human hair. The DNA of *E. coli* occupies only 1% of an *E. coli* bacterium (http://redpoll.pharmacy.ualberta.ca/CCDB/cgi-bin/STAT_NEW.cgi). One of the DNA segments that Dr. Harwood uses as a tracer is only a fraction of the length of the bacterial DNA. Thus it is obvious that Dr. Harwood is dealing with very tiny pieces of genetic material that cannot be assumed to move through the environment in the same way or at the same rate as living bacteria of that species or any other. Third, fecal indicator bacteria stick to soil surfaces, and this stickiness is partly a function of the properties of the outside of the bacterial cell surface. The surface of a living bacterium is not the same as the surface of a non-living piece of bacterial DNA. Dr. Harwood has not provided documentation that her tiny gene sequences move through the watershed to the same extent as do the living bacteria. Fourth, Dr. Harwood does not provide data to indicate how long her pieces of bacterial DNA persist in the environment. She made a general statement in her July 18, 2008 deposition (transcript page 12) that bacterial DNA may remain in the environment for a period of hours to several days. Living bacteria are capable of affecting humans only while they remain viable. Dr. Harwood provides no evidence that pieces of bacterial DNA can have any adverse effect on humans or any other species. In addition to these problems with respect to Dr. Harwood's assumptions about bacteria movement, it is also important to note that Dr. Harwood has not done any analyses that would shed light on the movement of P in the IRW.

Control of NPS water pollution requires first that one recognizes that there are multiple NPS sources. With that recognition, it is possible to implement a variety of BMPs that can effectively reduce the concentration of P and other constituents in stream water. This has been well demonstrated for one watershed within the IRW, as documented by Haraughty (1999). Oklahoma's first CWA Section 319(h) project was a demonstration of BMP effectiveness in the Battle Branch watershed over a three-year period. Public participation was high (84% of landowners). Installed BMPs included waste management plans, septic systems, dairy lagoons, poultry composters, waste storage structures, tree planting, and soil testing. About 80% of the P present was in the ortho-phosphate form (ortho-P). Ortho-P concentrations during baseflow events prior to BMP installation exhibited a mean of 0.067 mg/L. The mean baseflow ortho-P decreased to 0.024 mg/L after BMP installation. During storm flow conditions, the mean ortho-P decreased by more than an order of magnitude from 0.41 mg/L to 0.035 mg/L in response to installation of the BMPs (Haraughty 1999). It is noteworthy that these BMPs were not targeted in a punitive fashion to one industry, but rather resulted from voluntary adoption of a variety of practices among members of the entire community that resided within the watershed. Haraughty (1999, page 11) noted that, in the process of preparing the Comprehensive Basin Management Plan for the Oklahoma portion of the IRW,:

> ***Although some of these groups have specific interests in production activities within the basin, there was a noticeable lack of finger pointing. Each group recognized that the problems and causes were many and that contributions from all areas must be addressed.***